TECHNICAL NOTE

Introduction to ISO 10303 - the STEP Standard for Product Data Exchange

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Background

Since 1984 the International Organization for Standardization (ISO) has been working on the development of a comprehensive standard for the electronic exchange of product data between computer-based product life-cycle systems. Initial concentration has been on design and manufacturing applications. This standard, ISO 10303 [1,2,3], is informally known as STEP (STandard for the Exchange of Product model data). Its scope is much broader than that of other existing CAD data exchange formats, notably the Initial Graphics Exchange Specification (IGES), a US standard that has been in use for nearly twenty years. Whereas IGES was developed primarily for the exchange of pure geometric data between computer aided design (CAD) systems, STEP is intended to handle a much wider range of product-related data covering the entire life-cycle of a product.

The development of STEP has been one of the largest efforts ever undertaken by ISO. Several hundred people from many different countries have been involved in the work for the past sixteen years, and development is as active now as it ever has been in the past. STEP is increasingly recognized by industry as an effective means of exchanging product-related data between different CAD systems or between CAD and downstream application systems [4]. The first parts of the standard were published in 1994 [1,2] after some ten years of work by members of the relevant standards subcommittee, ISO TC184/SC4, whose responsibility is `Industrial Data'. Much of this effort went to developing an infrastructure for the standard that will ensure its extensibility for the foreseeable future.

ISO 10303 covers a wide variety of different product types (electronic, electro-mechanical, mechanical, sheet metal, fiber composites, ships, architectural, process plant, furniture,...) and life-cycle stages (design, analysis, planning, manufacture,...). This range is continually expanding as new parts of the standard are issued. These parts are referred to as ISO 10303-xxx, where xxx is the part number, and each is a standard in its own right, despite being a component of a larger whole and interdependent on other parts. Currently the overall standard is composed of about 40 parts, though many more are in development.

At present ISO 10303 exchanges usually employ the well-known neutral file approach, in which transfer between two systems is a two-stage process. In Stage 1 data is translated from the native data format of the originating system into the neutral ISO 10303 format, and Stage 2 is translation from the neutral format into the native format of the receiving system. The actual exchange medium in this case is an ASCII file. However, the standard makes a separation between the information model and its physical implementation, and this permits ISO 10303 models also to be used in other ways. For example, ISO 10303-022 has recently been published, defining a Standard Data Access Interface (SDAI) for repositories containing ISO 10303 neutral information. Bindings of the SDAI to several computer programming languages, including C++

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and Java, have been published or are in preparation. Other forms of data access and data sharing are in prospect for the future.

The entities to be captured and exchanged using STEP, and their relationships, are defined in schemas written in an information modeling language called EXPRESS [5]. This is part of the standard, and it is also used for similar purposes by other ISO standards. EXPRESS schemas are computer-processable and can be verified automatically for syntactical correctness and for the existence of appropriate links to other schemas. Instances of the defined entities form the actual exchanged data. Entity definitions include rules that can be checked at translation time to verify certain aspects of semantic validity of the transferred instances.

Components of STEP

The implementable parts of ISO 10303, i.e., those parts defining models on which translators are based, are known as Application Protocols (APs). Each AP is applicable to one or more life-cycle stages of a particular product class. However, the APs themselves are constructed on the basis of a set of Integrated Resources (IRs), defining fundamental constructs that can be specialized and applied for a wide variety of purposes.

The numbering system for parts of the standard is somewhat complex. Basically, the 01x series of parts is concerned with definitional resources and the 02x series with implementation methods. Standards in the 03x series deal with validation of translators for conformance with the standard. The 04x series contains Integrated Generic Resources, which provide the basic building blocks of the standard. However, there is also a higher-level set of Integrated Application Resources in the 1xx series. The Application Protocols appear in the 2xx series, though some of their basic reusable components have now been separately standardized in the 5xx series - these are known as Application Interpreted Constructs (AICs). The AIC philosophy is currently being pursued further, and the intention is that in future application protocols will be assembled from sets of reusable standard Application Modules.

The currently published resources and application protocols of the standard are as follows (January 2001):

Part 001 Overview and fundamental principles (1994)
Part 011 EXPRESS language reference manual (1994)
Part 021 Clear text encoding of the exchange structure (1994)
Part 022 Standard data access interface (1998)
Part 023 C++ language binding to the standard data access interface (2000)
Part 027 Java programming language binding to the standard data access interface with Internet/Intranet extensions (2000)
Part 041 Fundamentals of product description and support (1994)
Part 042 Geometric and toplogical representations (1994)
Part 043 Representation structures (1994)
Part 044 Product structure configuration (1994)
Part 045 Materials (1998)
Part 046 Visual presentation (1994)
Part 047 Shape variation tolerances (1997)
Part 049 Process structure and properties (1998)
Part 101 Draughting (1994)
Part 104 Finite element analysis (2000)
Part 105 Kinematics (1996)

AP 201 Explicit draughting (1994)

AP 202 Associative draughting (1996)
AP 203 Configuration-controlled design (1994)
AP 207 Sheet metal die planning and design (1999)
AP 224 Mechanical product definition for process planning using machining features (1999)
AP 225 Building elements using explicit shape representation (1999)

The dates given are dates of first publication, but more recent second editions of some of the listed STEP parts are now available. Additionally, the following application protocols are complete and awaiting publication by ISO at the time of writing:

AP 210 Electronic assembly, interconnection and packaging design
AP 212 Electrotechnical design and installation
AP 227 Plant spatial configuration

Geometry Data Exchange

The part of STEP that is currently most widely used is application protocol AP 203 ('Configuration-controlled design'). This is concerned with the transfer of product shape models, assembly structure, and configuration control information (e.g. part versioning, release status, authorization data etc.) It may be regarded as an IGES replacement, though in fact it goes some way beyond the capabilities of IGES. Product shape models in AP 203 are explicit non-parametric models of the boundary representation and closely related types. Work is in progress on extensions for the transfer of parametric shape models and of procedural models defined in terms of their constructional history. The assembly models that can be exchanged using AP 203 are collections of positioned and oriented part models, suitable for the generation of parts lists and bills of materials. Methods for capturing feature-based inter-part relationships in assemblies are currently under development.

Each STEP Application Protocol defines a set of Conformance Classes. These specify subsets of the total AP content that must be completely implemented by STEP translators if they are to claim conformance with the standard. The AP 203 conformance classes are as follows:

CC1: Configuration-controlled design information without shape;
CC2: Class 1 and shapes represented by geometrically bounded wireframe models, surface models, or both;
CC3: Class 1 and shapes represented by wireframe models with topology;
CC4: Class 1 and shapes represented by manifold surface models with topology;
CC5: Class 1 and shapes represented by faceted boundary representation;
CC6: Class 1 and shapes represented by advanced (i.e., non-faceted) boundary representation.

As can be seen from the above, all validated AP 203 translators must provide the Class 1 configuration control data, and they may additionally handle any combination of the shape representation possibilities. Testing laboratories have been set up around the world, and they have already validated a significant number of commercially produced STEP translators for adherence to various conformance classes of AP 203, the most popular being CC6. The range of such testing will broaden as more parts of STEP become widely used by industry.

All major mechanical CAD vendors now have STEP translators available, mostly for AP 203, but increasingly for AP 214 ('Core data for automotive mechanical design processes'). This has not yet been published by ISO (that will probably happen early in 2001) but it is anticipated that AP 214 will be widely used once it appears because its scope is considerably wider than that of AP 203. For example, it handles raw materials data, manufacturing tools and plans for a range of manufacturing methods, standard (catalog) parts, tolerance data, features, numerical control (NC) data, data for kinematic simulation, 2D drawings, and certain classes of product data management (PDM) information. There is some overlap with AP 203, notably in the area of shape models, and CAD vendor companies are gradually tackling the many conformance classes of AP 214 by extending the AP 203 translators they have already developed.

Difficulties in geometry data exchange involve (i) accuracy issues, (ii) “model quality” issues, and (iii) entity mismatch issues. These problems will be discussed in a future article.

Discussion

Several problems have emerged in recent years relating both to the unprecedented scale of the ISO 10303 standard and to the necessity for it to track new developments in technology as they occur. The latter is not easy, because the ISO standardization process involves intensive international consensus-seeking and lengthy review and balloting procedures at several stages during the development of each standard specification. In consequence, different approaches for bringing documents to the International Standard status are being tried, and the entire structure of the STEP standard is currently in process of revision to make the development process faster and more flexible while requiring less voluminous documentation. These changes will also provide interoperability between different parts of the standard, allowing (for example) the linked use of a mechanical engineering AP with an electrical one. A further important aspect of current activity in the STEP community is harmonization with developing standards in related fields. To give just one example, there is strong emphasis at the moment on the use of XML as a means of capturing and transferring STEP information.

The references below include the documents, books and Web site cited earlier. Reference [4] gives details of several industrial achievements resulting from the use of STEP data exchange (follow the link to 'Success Stories'). Additionally, the addresses of three further relevant Web sites are provided. The first [6] gives a succinct (one-page) overview of the status of all the parts of the STEP standard. The second [7] is the STEP Online Information Server (SOLIS) based at NIST, which provides a wealth of information concerning STEP documents under development. The third [8] gives the URL of the US Product Data Association (USPro), from whom published ISO 10303 standards documents are available in the USA; elsewhere, they are available from ISO in Geneva, Switzerland [1], or through appropriate national standards organizations.

References

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2. J. Owen, STEP: An Introduction, Information Geometers, Winchester, UK, 2nd edition, 1997 (ISBN 1-874728-04-6).
3. S. J. Kemmerer (ed.), STEP: The Grand Experience, NIST Special Publication SP 939, US Government Printing Office, Washington, DC 20402, USA, July 1999.
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6. NIST, STEP-on-a-page, http://www.mel.nist.gov/sc5/soap/
7. NIST, STEP Online Information Server, http://www.nist.gov/sc4/
8. USPro, Home page, https://www.uspro.org

<u>Editor’s Note</u>: Tracking of data exchange standard will be a regular feature of JCISE. Future Technical Notes will include reviews of specific parts of STEP.