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Data Sharing Implementation Based on the Information Model for Apparel Pattern Making

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ABSTRACT

A standard neutral file format for facilitating apparel pattern data sharing among dissimilar CAD/CAM systems has been long awaited by the apparel industry. The National Institute of Standards and Technology (NIST) has taken the approach to use the Standard for the Exchange of Product Model Data (STEP) methodology to develop an information model for the exchange of two-dimensional flat patterns. STEP, being developed in the International Organization for Standardization (ISO), provides a representation of product information along with the necessary mechanisms and definitions to enable product data to be exchanged amongst different computer systems and environments.

STEP defines a specification language called EXPRESS that is used to represent the information model within STEP. This paper presents an EXPRESS information model, in a graphical notation, for the communication of structure and semantics of the apparel pattern data necessary to inter-operate between different CAD systems. The information model supports the capabilities of representing the base pattern geometry, the sizing data, and the grading rules which are based on traditional X-Y pattern-grading methods. Prototype implementation of the information model is also described in the report.

Keywords: apparel, APDES, data exchange, EXPRESS, information model, pattern, product data, prototype implementation, STEP

1 INTRODUCTION

Today's corporations are driven to electronically exchange information. Competition drives the introduction of new products, improving information sharing is one way to reduce the time to market. The apparel industry has used computer systems to automate many of its manufacturing processes. However, the manufacturing innovations often stand alone as "islands of automation." Integrating the separate automated processes could greatly improve the effectiveness of the entire enterprise. In recent years, the National Institute of Standards and Technology (NIST), under the sponsorship of the Defense Logistics Agency (DLA), has been developing the apparel product data exchange standard (APDES) [1]. The goal of the APDES project is to develop comprehensive specifications for sharing apparel product data among all stages of the product life cycle.

As a first step in the APDES development, the APDES project team at NIST has determined a preliminary set of manufacturing data interfaces that could be standardized for the effective integration of the information systems required to operate an apparel manufacturing enterprise [2]. The specification of these manufacturing data interfaces is being developed based on the Standard for the Exchange of Product Model Data (STEP) methodology [3]. STEP is an emerging international standard, the result of an effort to develop a mechanism for digitally representing the physical and functional characteristics of a product throughout the product's life cycle. STEP includes definitions of information models and mechanisms for representing the models and related data. The information models provide a mechanism to communicate the structure and the semantics of the data necessary to exchange among different computer systems and environments. In 1994, the twelve documents that make up the initial release of STEP were published as International Standard ISO 10303. The initial release includes information resources that are general enough to support multiple industries, and specific application protocols for 3-dimensional drafting and design.

In 1993, the American Apparel Manufacturers Association (AAMA) published a pattern data interchange standard, ANSI/AAMA-292 [4]. The standard was developed by building apparel conventions into the AutoDesk's AutoCAD Version 11 DXF (drawing interchange) file format. While implementing the ANSI/AAMA-292 standard, problems have been identified. With vendors' cooperation, the standard is now getting close to be implemented successfully [5]. Since DXF is not an official standard format[1] and it could be changed under the discretion of AutoDesk, Inc., the ANSI/AAMA-292 can only be considered as a near-term solution for pattern data exchange.

An information model for pattern data interchange (or simply named "Pattern Information Model") to support the manufacturing data interfaces has been developed using the EXPRESS conceptual modeling language [6]. The EXPRESS language has been developed as part of the STEP activities. Currently, the language has two forms: EXPRESS and EXPRESS-G. EXPRESS itself is a computer processible lexical language and EXPRESS-G is a formal graphical notation for the display of data specifications defined in EXPRESS. Along with the EXPRESS language, STEP also specifies an exchange structure format using a clear text encoding of product data for the EXPRESS information model [7]. The exchange structure file format is one implementation method, through the use of the EXPRESS information model, for communicating information about products. Other implementation methods include the use of a standard in-memory data format, a database management system, and an object-oriented database that utilizing knowledgebase system technology [8].

A computer program to support the prototype implementation of the Pattern Information Model has been developed. The program, together with its front-end modules that have been developed by NIST and are available in the public domain, has served as a STEP/Pattern Information Model translator. The translator can be used to exchange pattern data exchange between the STEP

1. An official standard format is the specification that was developed using a consensus process such as from an accredited national or international standards making body.

exchange structure file format and the ANSI/AAMA-292 file format. The Pattern Information Model in the EXPRESS-G form is shown in section 2. Section 3 describes the issues related to the prototype implementation of the model. The final section concludes the report.

2 INFORMATION MODEL

The Pattern Information Model that is presented in this section specifies the information necessary to represent two-dimensional flat patterns for the purpose of facilitating communication between apparel CAD/CAM pattern making systems. It defines the data types that can be used to define two-dimensional patterns generated by the traditional ready-to-wear pattern making and grading. Section 2.1 defines terms that are used in the Pattern Information Model. Section 2.2 presents the EXPRESS-G information model that includes ten figures: figures 2.2.1 through 2.2.10.

2.1 Definition of Types and Entities

The following lists definitions of types and entities that are used in the section 2.2, *EXPRESS-G* figures.

ANNOTATION_FEATURE: An *annotation_feature* entity is an annotation on the pattern piece presented for informative purposes; it does not represent a feature of the cut piece. It consists of a text string and a *line* for locating and orienting text.

ARC: An *arc* entity specifies an arch-shaped segment of a curve for which no particular geometric form, such as circle, ellipse, or parabola, is specified.

BASIC_PATTERN_PIECE: A *basic_pattern_piece* entity defines the base shape of one pattern piece of a garment for a particular size.

BOUNDED_CURVE: A *bounded_curve* entity is an abstraction of *arc* entity and *polyline* entity.

COMPOSITE_CURVE_FEATURE: A *composite_curve_feature* entity is a geometric entity that defines a curve in the drawing; it may contain many curve segments.

COMPOSITE_CURVE_FEATURE_TYPE: A *composite_curve_feature_type* provides a means of expressing the purpose of a curve on a pattern piece. This type is an enumeration of boundary cut, internal cut out, fold line, and sew line. It is used as the type of an attribute defined in the *composite_curve_feature* entity.

GRADE_DATA_AT_POINT: A *grade_data_at_point* entity is an ordered collection of the displacements of the specified grading point for a set of pre-defined grading sizes.

GRADE_DELTA: A *grade_delta* entity specifies a displacement vector on a drawing. It consists of the amounts of growth in the *X* and *Y* directions at the grade point between two grading sizes.

GRADE_POINT: A *grade_point* entity specifies a point on a pattern piece that is subject to a grading rule. The grade point on a pattern piece is subject to a grading rule.

GRADE_RULE_AT_POINT: A *grade_rule_at_point* is an abstraction of the *grade_data_at_point* entity, and the *library_rule_at_point* entity.

GRADE_RULES_OF_PIECE: A *grade_rules_of_piece* entity contains the information for grading a pattern piece for a set of pre-defined sizes.

GRADE_RULES_OF_PATTERN: A *grade_rules_of_pattern* entity contains the information for grading a pattern for a set of pre-defined sizes.

LIBRARY_RULE_AT_POINT: A *library_rule_at_point* entity specifies a grade rule identifier or label in the rule library that defines how an associated grade point on a pattern piece grows in the X and Y axes for each size in reference to the base size.

LINE: A *line* entity defines a line segment. It consists of two *point*s.

MARK_FEATURE: A *mark_feature* entity specifies a drill hole, a lift and plunge point, a stacking point, a facing point, or a cut entry point on the pattern piece.

MARK_FEATURE_TYPE: A *mark_feature_type* provides the means to indicate a mark on the pattern. This is used as an aid for subsequent cutting and sewing processes. *Mark_feature_type* is an enumeration of drill hole, lift and plunge point, stacking point, facing point, and cut entry point. It is used as type of an attribute defined in the *mark_feature* entity.

MEASUREMENT_UNIT_TYPE: A *measurement_unit_type* provides a means to define the units of length. *Measurement_unit_type* is an enumeration of centimeter and inch.

NOTCH_FEATURE: A *notch_feature* entity specifies a notch on the seam line or on the perimeter of a pattern piece. *Notch_feature* is an abstraction of the *v_notch* entity and the *slit_notch* entity.

ORIENTATION_CONSTRAINT: An *orientation_constraint* entity is a direction specification on the pattern piece.

ORIENTATION_CONSTRAINT_TYPE: An *orientation_constraint_type* provides a means of specifying the orientation of the pattern piece or supporting symmetrical pattern pieces. *Orientation_constraint_type* is an enumeration of grain reference line, stripe reference line, plaid reference line, and mirror line. It is used as the type of an attribute defined in the *orientation_constraint* entity.

PATTERN: A *pattern* entity belongs to a garment and defines the garment shape for a particular size.

PATTERN_GEOMETRY_ENTITY: A *pattern_geometry_entity* is an abstraction of *mark_feature* entity, *notch_feature* entity, *orientation_constraint* entity, *annotation_feature* entity, and *composite_curve_feature* entity.

PATTERN_MIRROR_TYPE: A *pattern_mirror_type* provides the means to identify the mirror information of the pattern piece. It is an enumeration of the basic, horizontal mirror, and vertical mirror. A mirror pattern is a mirror-image of the basic pattern in the horizontal or vertical direction. *Pattern_mirror_type* is used as the type of an attribute defined in the *pattern_piece* entity.

PATTERN_PIECE: A *pattern_piece* entity defines a pattern piece of a garment for a particular size and the total number of this piece required in the garment.

PATTERN_SIZE: *A pattern_size* entity specifies a garment size designation for a given compilation of anthropometric measurements. With this designation, the garment will fit someone whose measurements lie within certain range limits of the size measurements.

POINT: A *point* entity specifies a location on a pattern piece.

POLYLINE: A *polyline* entity is a bounded curve of line segments. It consists of an ordered collection of points that are connected using straight lines.

SLIT_NOTCH: A *slit_notch* entity specifies an angled slit cut on the pattern piece.

READY_TO_WEAR_PATTERN: A *ready_to_wear_pattern* entity defines graded pattern of a garment for all sizes.

V_NOTCH: A *v_notch* entity specifies a v-shaped cut on the pattern piece.

2.2 EXPRESS-G FIGURES

In this section, the Pattern Information Model is presented in EXPRESS-G, a graphical subset of the EXPRESS Language. EXPRESS-G is defined in Annex D of ISO 10303-11:1994(E), EXPRESS Language Reference Manual [6].

An EXPRESS schema is composed of declarations of types, entities, constraints, and their relationships. In EXPRESS, entities are defined in terms of attributes. These attributes have a representation which might be a simple data type or another entity data type (such as aggregation data type, user-declared data type, enumeration data type, select data type, and generalized data type.) The simple data types represent atomic units of data; they can not be further subdivided into elements that EXPRESS recognizes; the simple data types are NUMBER, REAL, INTEGER, STRING, BOOLEAN, LOGICAL and BINARY. The aggregation data types are used to represent ordered or unordered collections of instances; there are four kinds of aggregation data types: ARRAY, LIST, BAG and SET. The user-declared data types are established by ENTITY declarations or TYPE declarations. An enumeration data type is an ordered list of values represented by names; these names are designated by enumeration items. A select data type defines a named collection of other data types called a select list; a value of a select data type is a value of one of the data types specified in a select list. The generalized data types are used to specify a generalization of certain other data types, and can only be used in certain very specific contexts.

EXPRESS-G is represented by graphic symbols forming a diagram. The notation has three types of symbols: definition (symbols denoting schema declaration and data types declarations), relationship (symbols describing relationships which exist among the definitions), and composition (symbols enabling a diagram to be displayed on more than one page.) The three types of symbols are briefly shown in Table 2.a.

The complete information model is presented in Figure 2.1 through figure 2.10. Table 2.b lists the entities that presented in each of the ten figures.

Table 2.a Symbols for EXPRESS-G

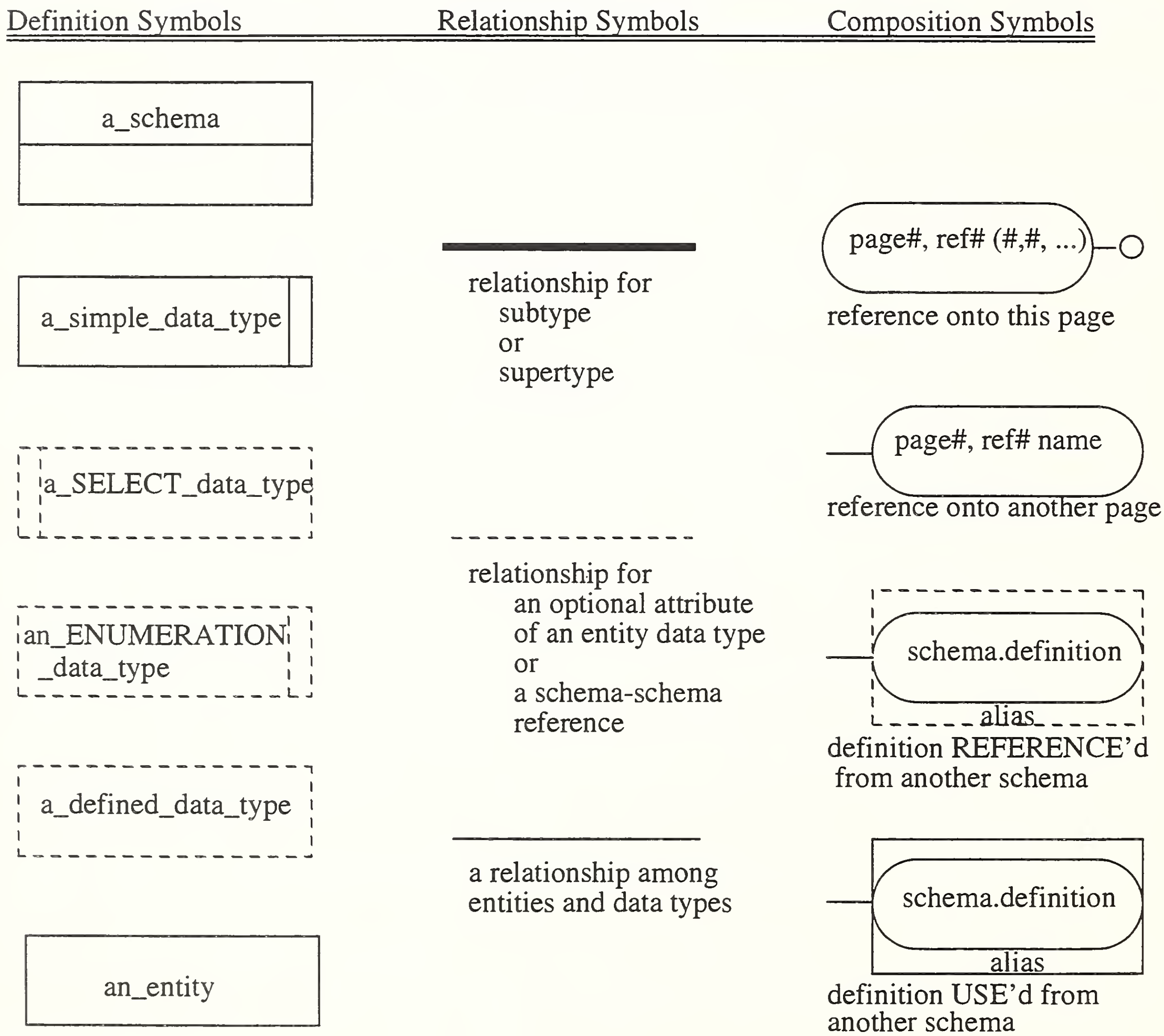

Table 2.b Entities of the Pattern Information Model

Figure #	Contents / List of Entities	
Figure 2.1	ready_to_wear_pattern	
Figure 2.2	pattern _size	
Figure 2.3	grade_rules_of_pattern	grade_rules_of_piece
Figure 2.4	grade_rule_at_point	grade_data_at_point
	library_rule_at_point	grade_point
	grade_delta	
Figure 2.5	pattern	pattern_piece
	basic_pattern_piece	
Figure 2.6	pattern_geometry_entity	
Figure 2.7	composite_curve_feature	bounded_curve
	arc	polyline
Figure 2.8	notch_feature	v_notch
	slit_notch	
Figure 2.9	mark_feature	annotation_feature
	orientation_constraint	
Figure 2.10	line	point

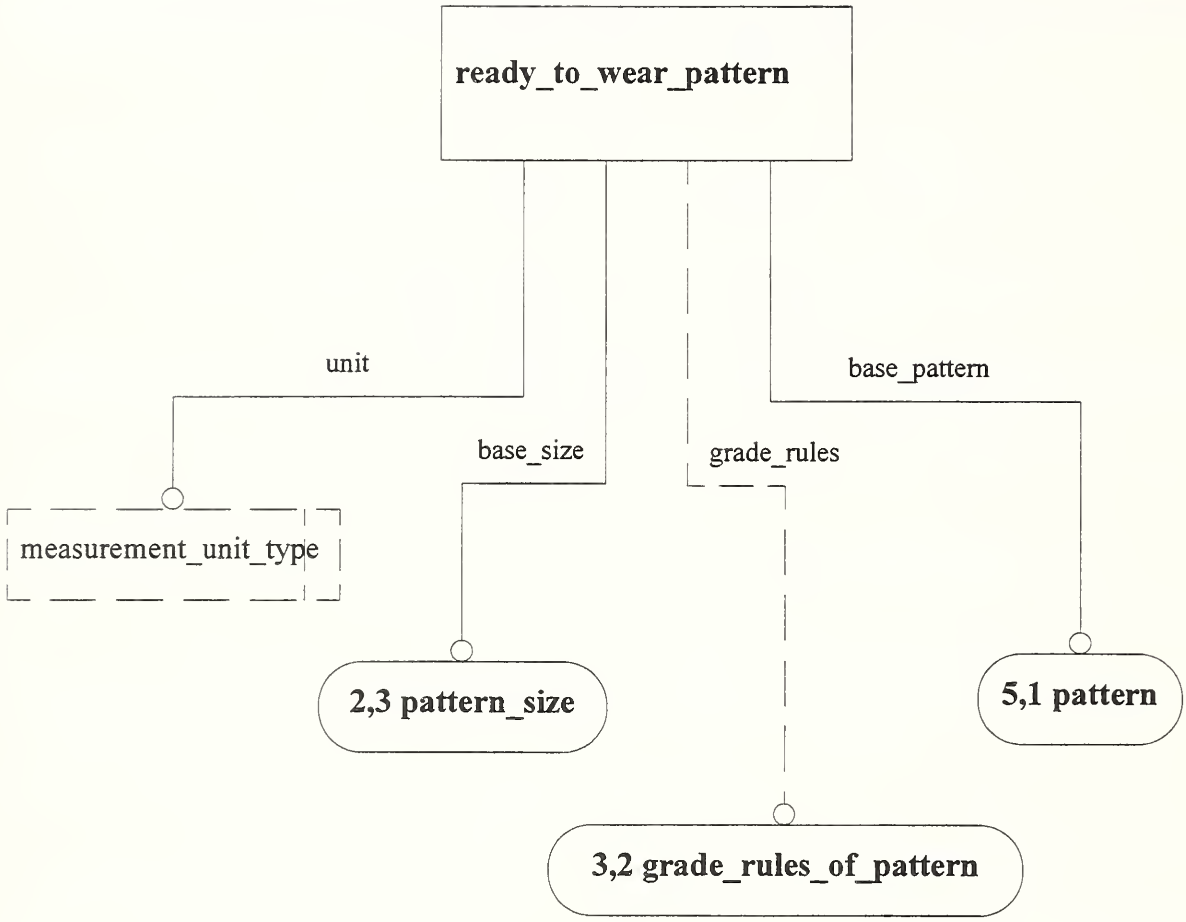

Figure 2.1 -- EXPRESS-G diagram 1 of 10

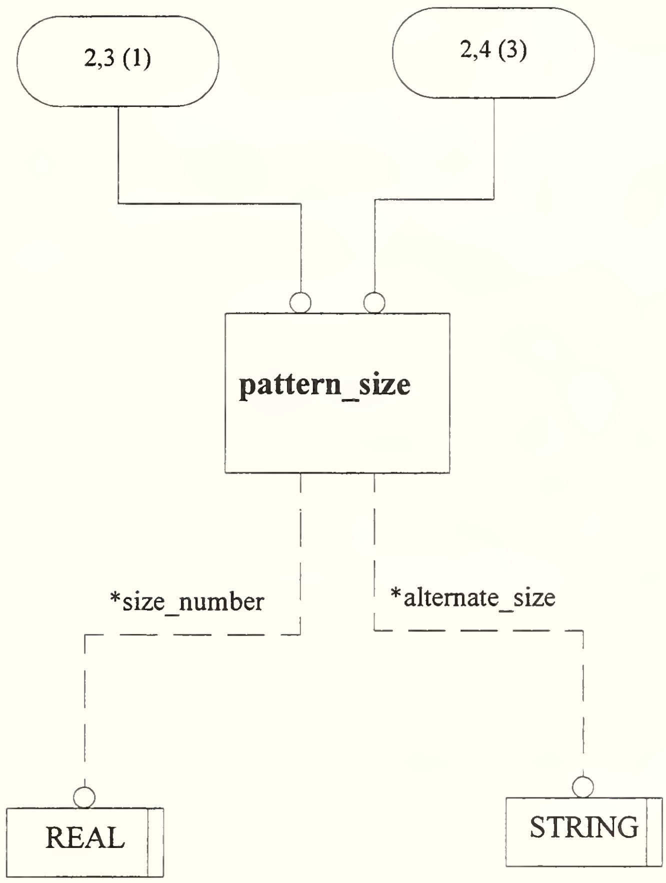

Figure 2.2 -- EXPRESS-G diagram 2 of 10

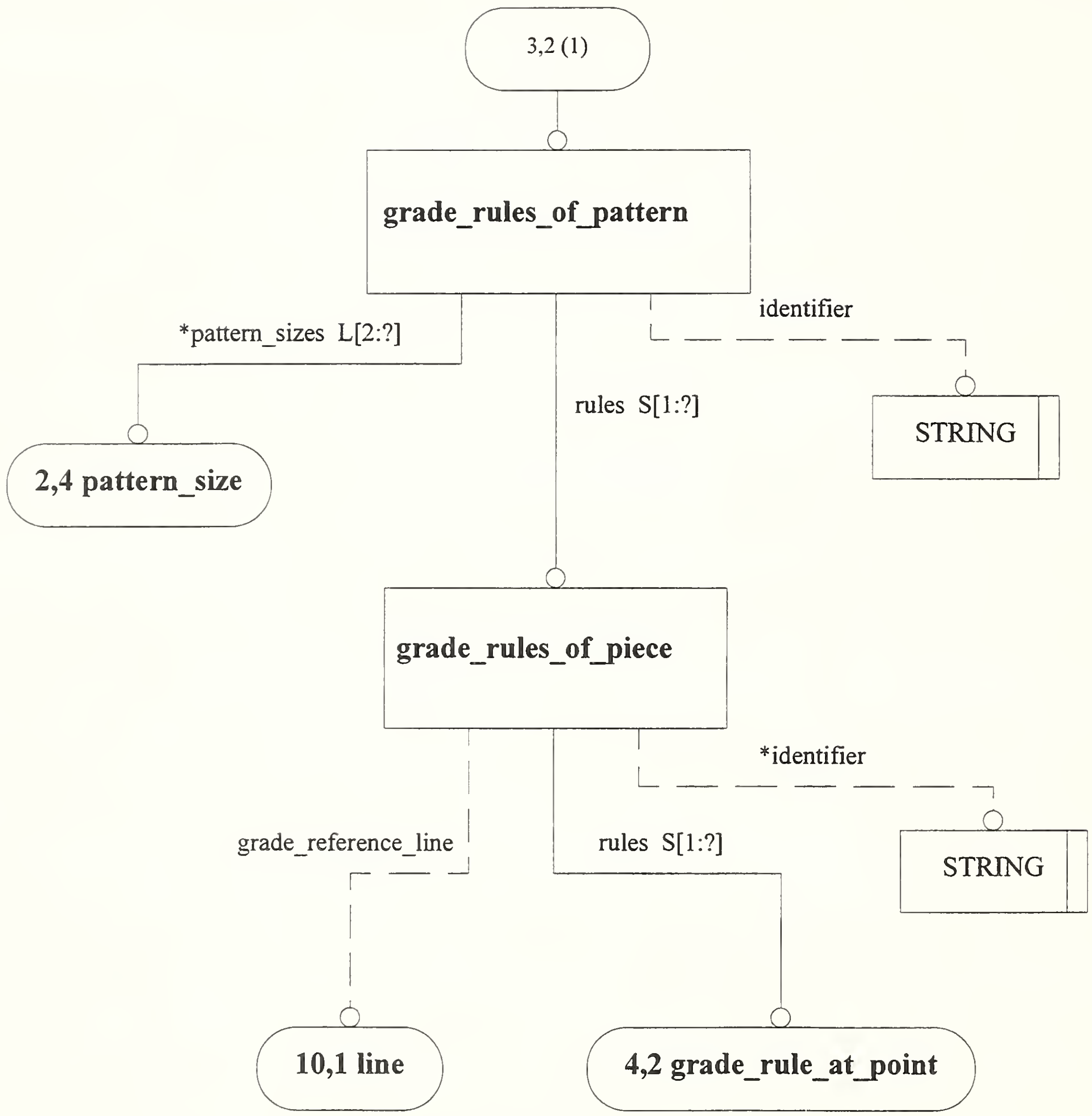

Figure 2.3 -- EXPRESS-G diagram 3 of 10

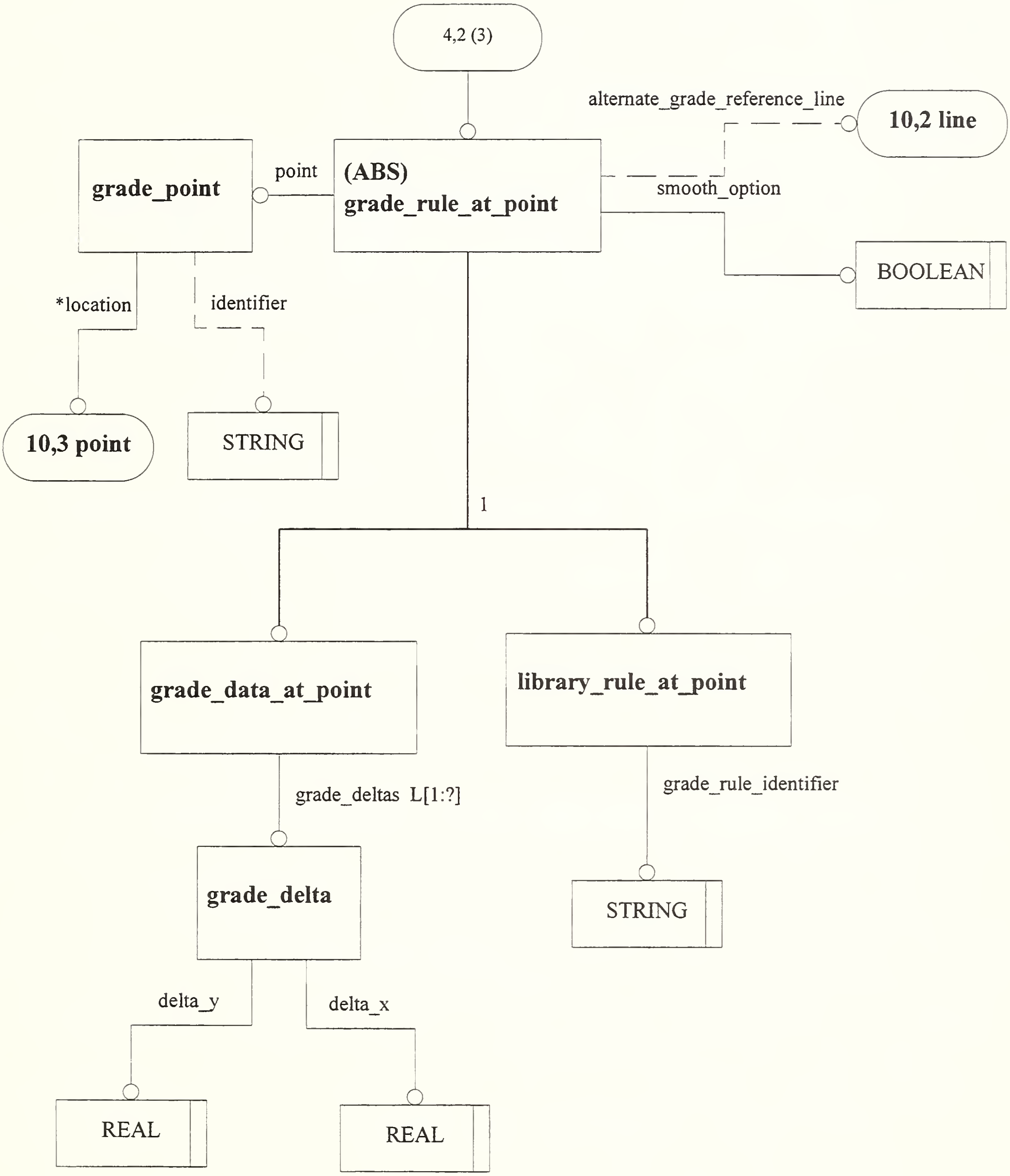

Figure 2.4 -- EXPRESS-G diagram 4 of 10

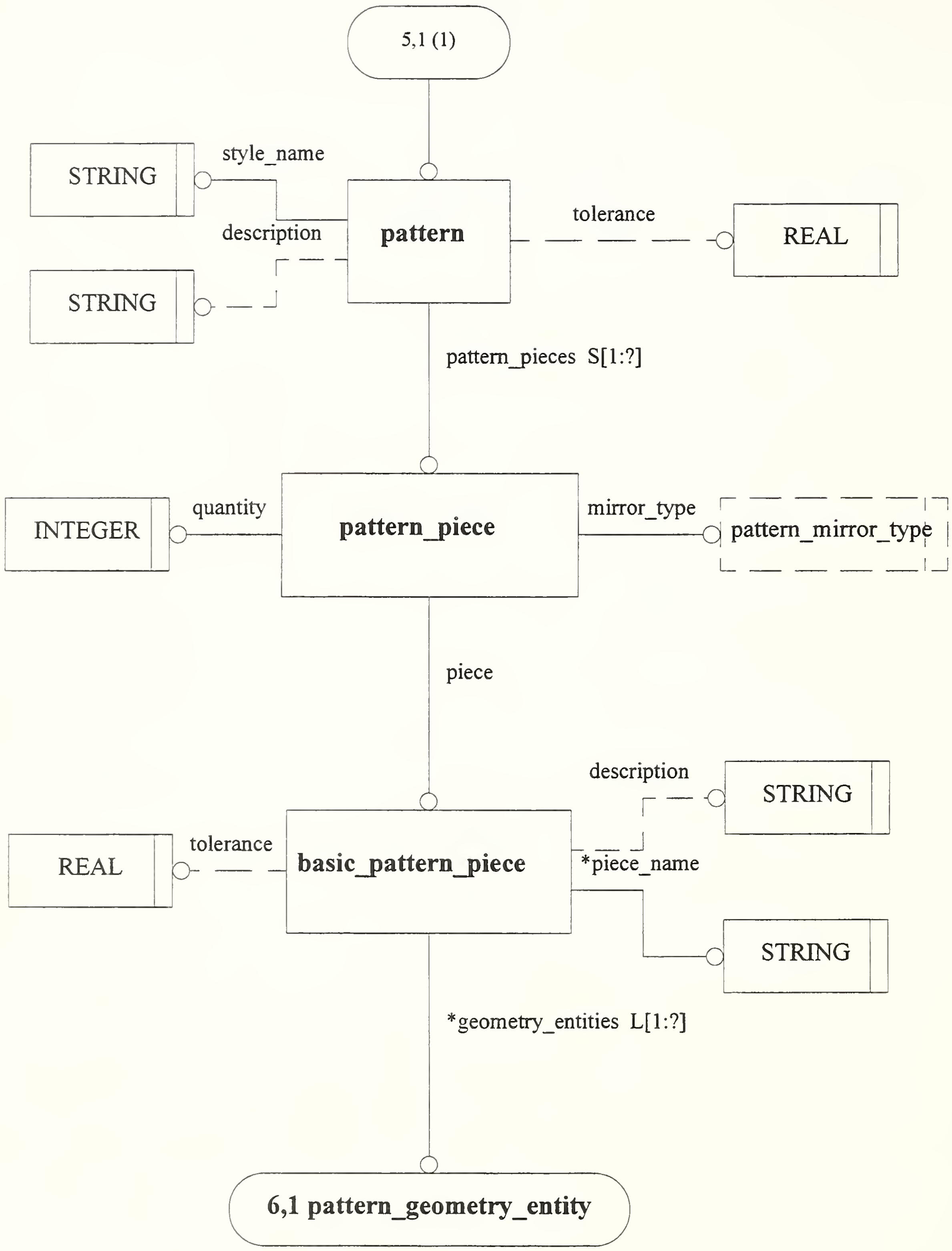

Figure 2.5 -- EXPRESS-G diagram 5 of 10

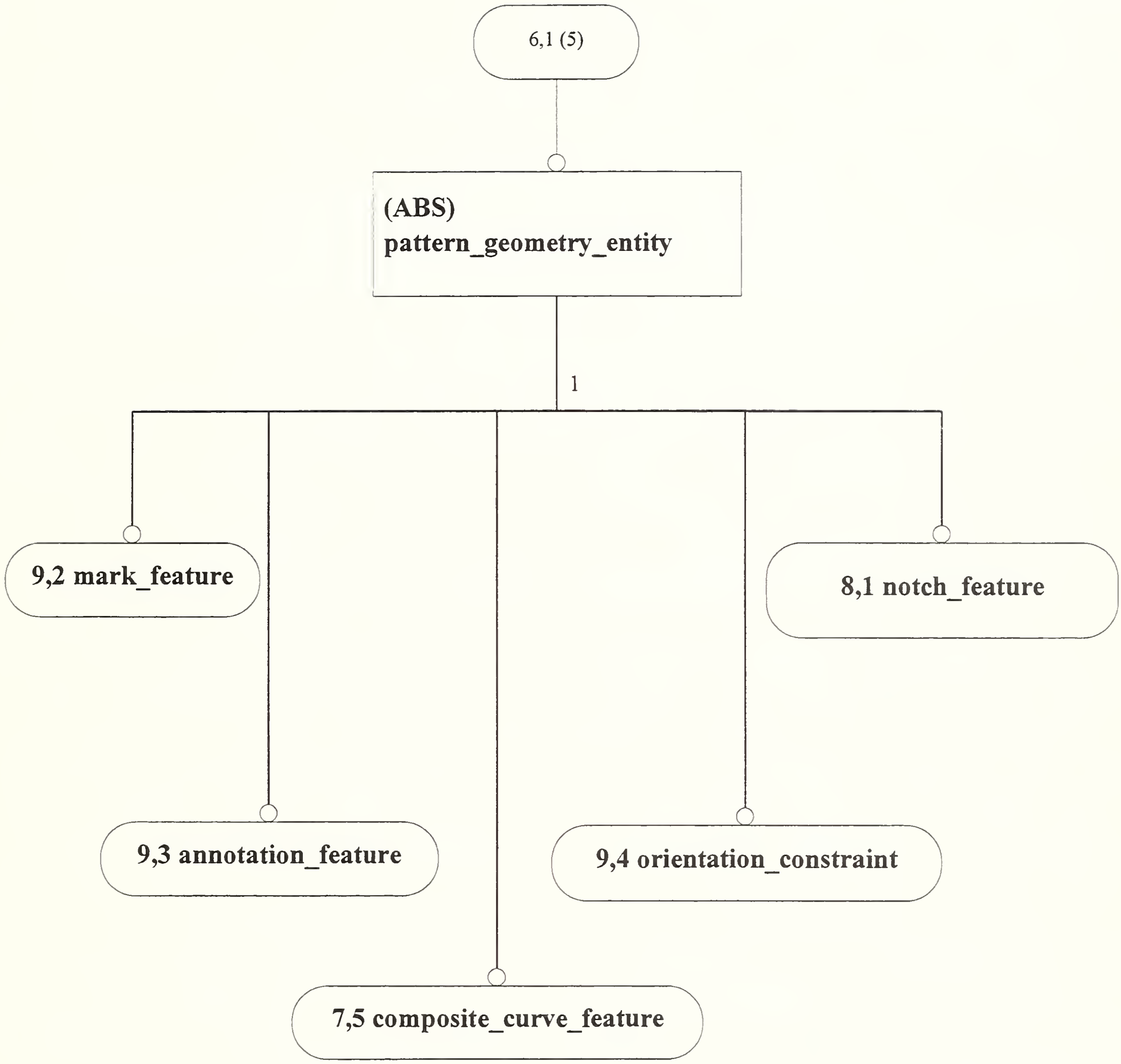

Figure 2.6 -- EXPRESS-G diagram 6 of 10

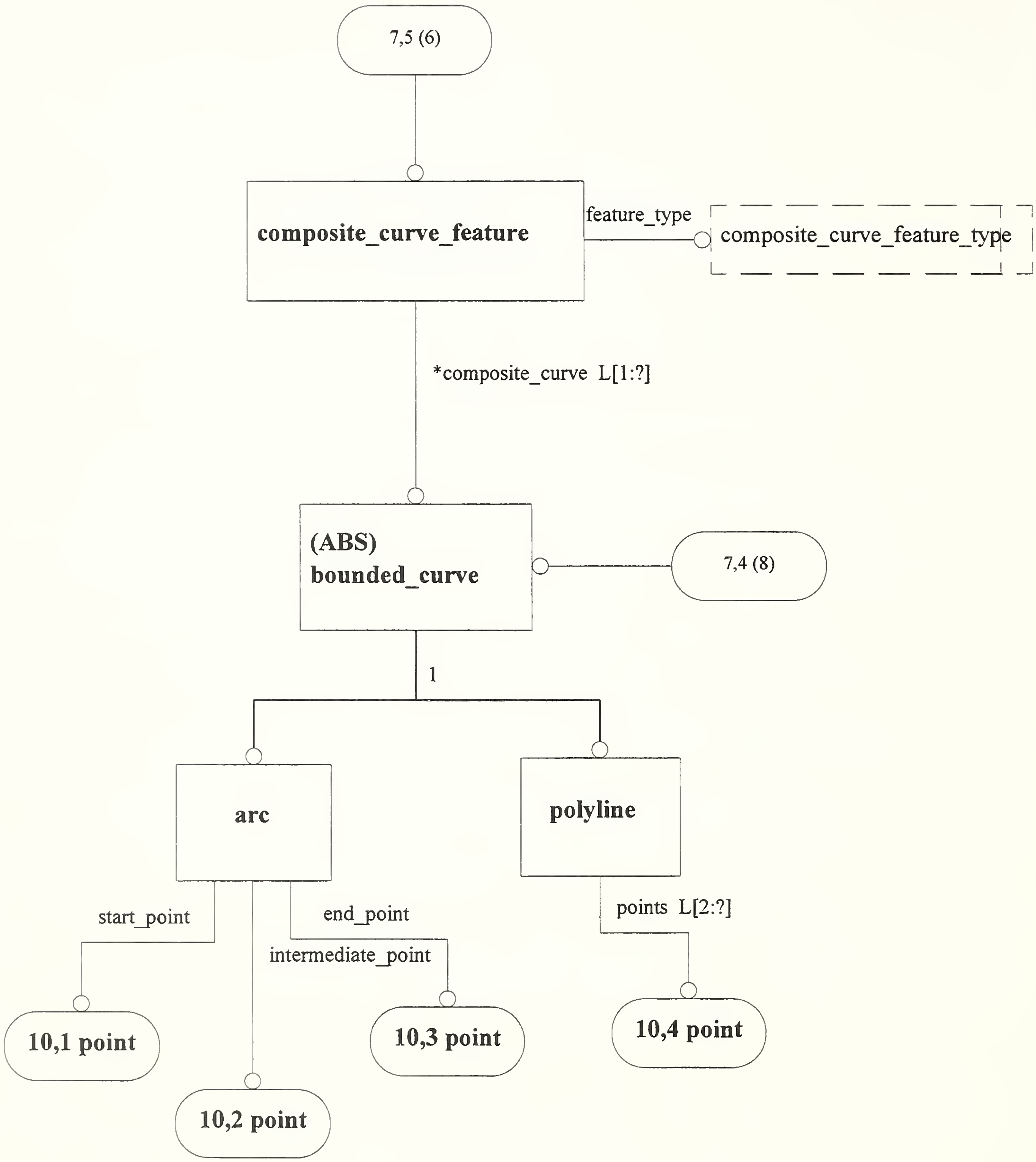

Figure 2.7 -- EXPRESS-G diagram 7 of 10

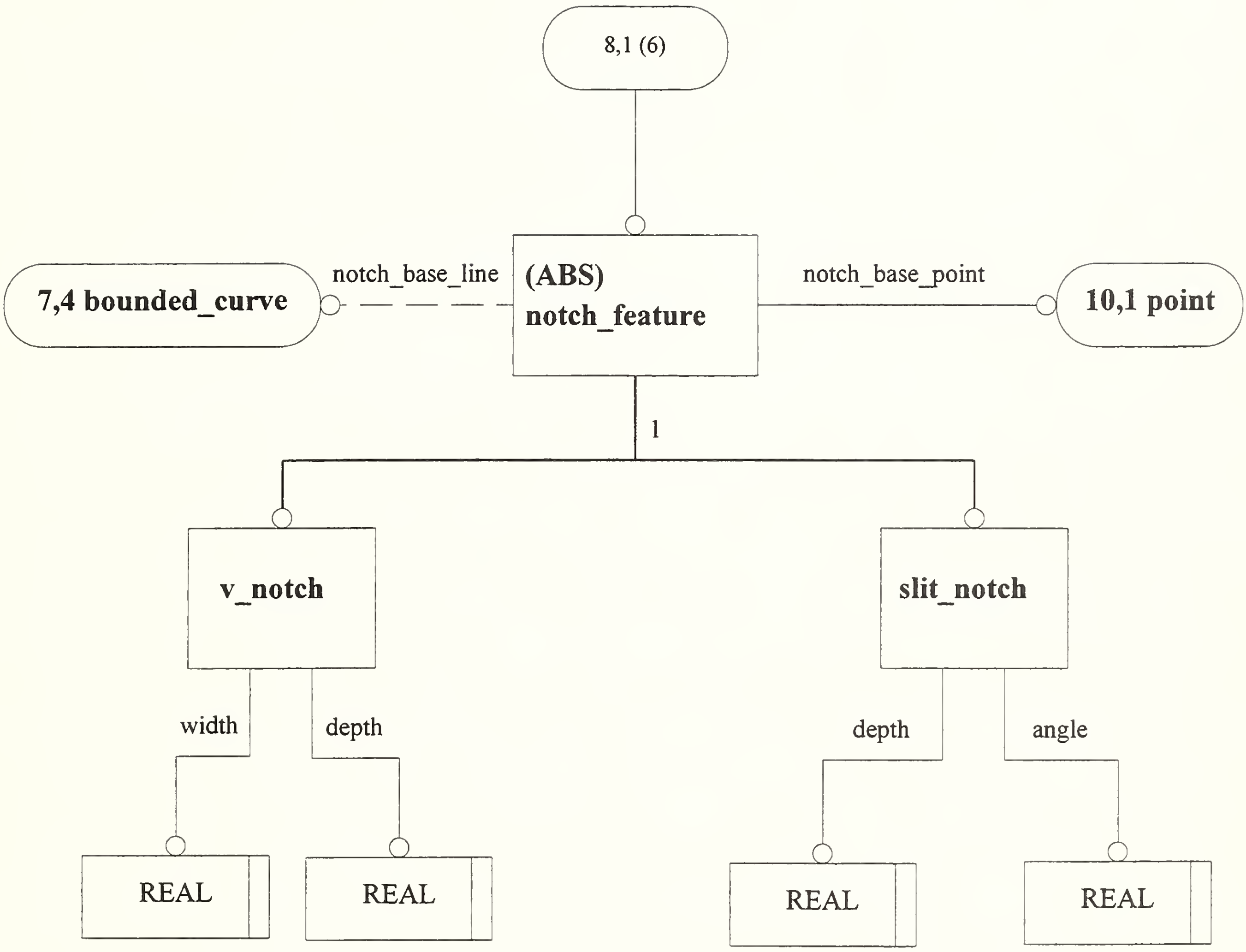

Figure 2.8 -- EXPRESS-G diagram 8 of 10

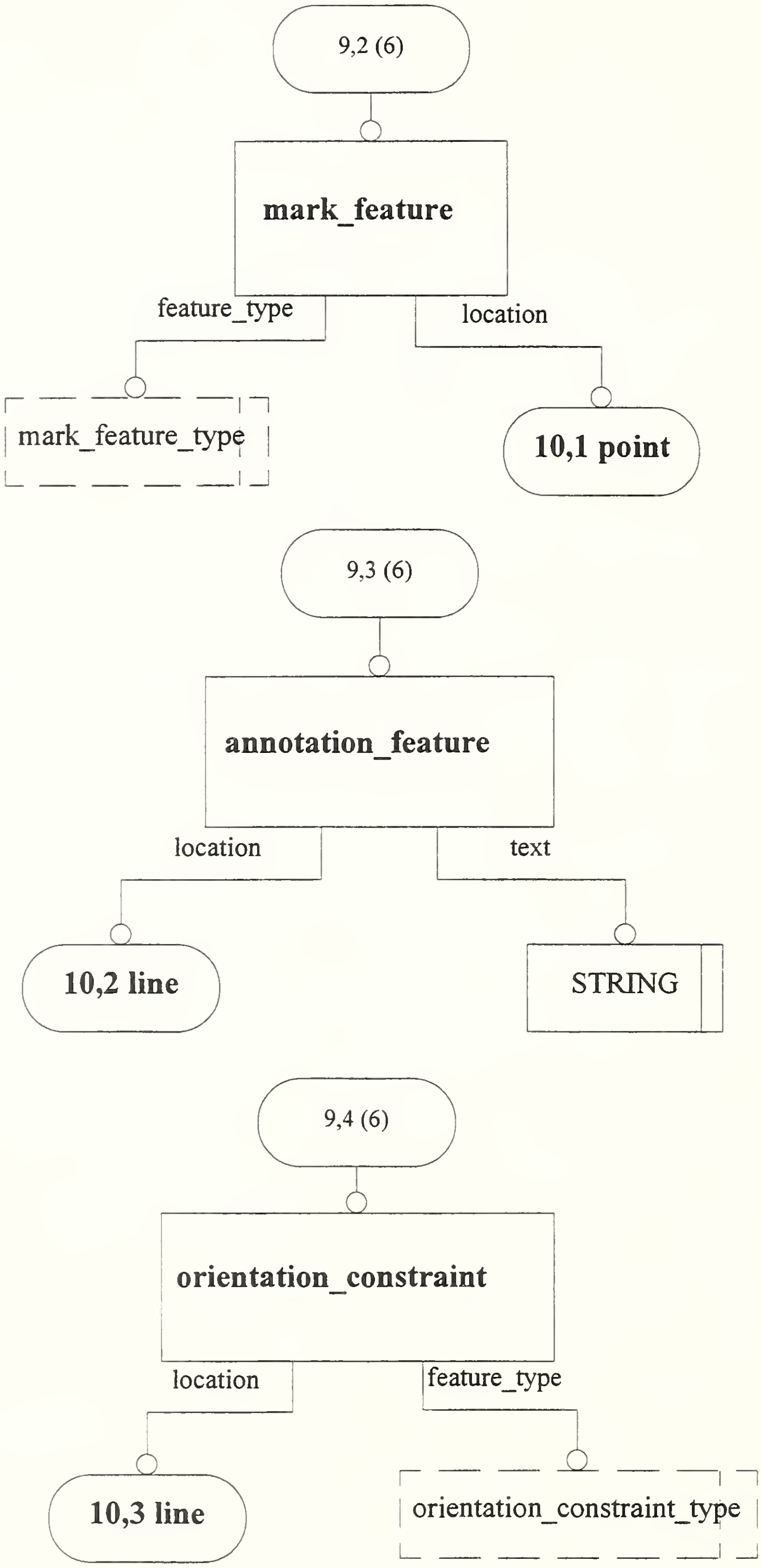

Figure 2.9 -- EXPRESS-G diagram 9 of 10

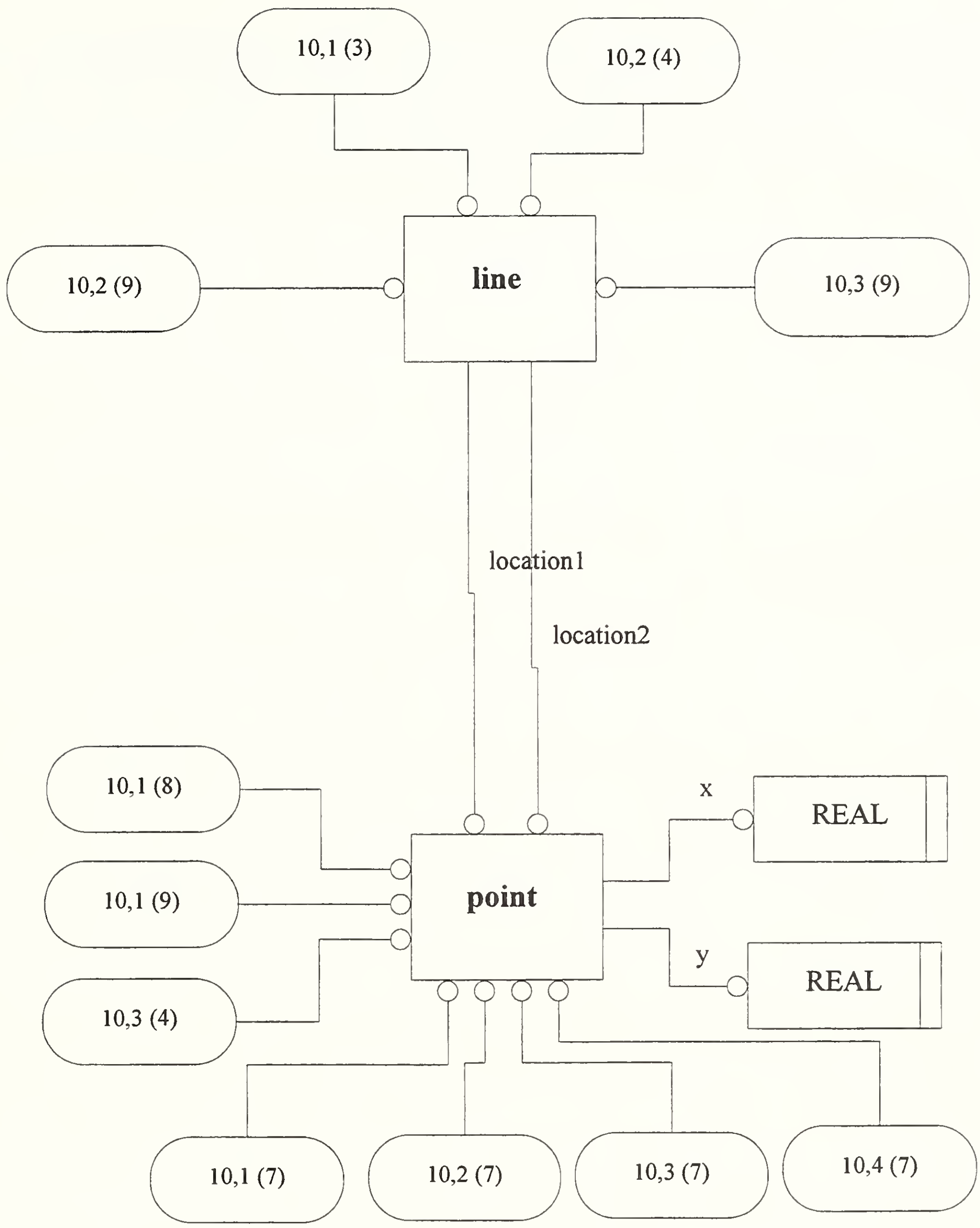

Figure 2.10 -- EXPRESS-G diagram 10 of 10

3 DATA SHARING IMPLEMENTATION

The fundamental components of STEP include definitions of information models and mechanisms for data sharing using the models. The Pattern Information Model was introduced in section 2. Implementation issues, such as mechanisms for the implementation of the Express information models and supporting software tools for read/write/edit data files, etc., are described in this section.

3.1 Implementation Methods

The STEP community has introduced "four levels" of data sharing implementations through the use of standard information models [8]. These four levels of implementation are:
Level 1 - Data sharing by means of an exchange file in a standard format,
Level 2 - Data sharing via a working form that is a structured in-memory representation of data,
Level 3 - Data sharing using a database management system, and
Level 4 - Data sharing using a knowlegebase system.

The Technical Committee ISO/TC 184 (Industrial Automation Systems and Integration, Subcommittee SC4, Industrial Data) has published several documents related to the issue of the implementation method. "ISO 10303-21: 1994(E) Implementation Methods - Clear Text Encoding of the Exchange Structure" specifies an exchange structure format that is used in STEP exchange files for product data. The form of product data in the exchange structure is also specified using a mapping from the Express Language [7]. Another document, "ISO 10303-22:1996(E) Implementation Methods: Standard Data Access Interface," specifies the standard data access interface (SDAI) to data defined using EXPRESS [9]. The ISO 10303-22 specifies the requirements of a programming interface for the creation and manipulation of instances of EXPRESS entities. The SDAI operations are given independent of any programming language. SDAI language bindings are specified for the particular programming languages, such as C++ language, to define the capabilities required of the implementations [10].

3.2 Software Tools

Several commercial and non-commercial software tools exist to support the implementation of EXPRESS information models [11]. The apparel industry can take advantage of these software tools to generate various types of data structures from the Pattern Information Model in order to benefit the exchange of pattern data between CAD/CAM systems.

In recent years, NIST has released a variety of software tools for manipulating STEP data. The software tools are in the public domain and are also available from the SC4 On-Line Information Service [12]. The following presents some of NIST's software tools that support the manipulation of the STEP exchange files.

1) The NIST EXPRESS Toolkit is an EXPRESS parser that reports syntactic and semantic errors in the Express information model. The parser populates a set of data structures containing all the information in an EXPRESS specification. A user-supplied back-end modules can then walk through the data structure and produce various formatted output modules.

2) The Part 21 Toolkit is a software library for building software tools for manipulating STEP data provided in the STEP exchange structure format. An output generation back end can be added to the Toolkit to build a STEP translator. The p21 program, an example application, loads a STEP physical file into the STEP Working Form and reports syntactic and semantic errors in either the data file or the EXPRESS information model.

3) Data Probe Tool is a collection of software that is used to build an information model specific Data Probe. The information model, however, must be written in EXPRESS. The Data Probe is a prototype STEP and EXPRESS schema browser and editor; it is used to read, write, edit and browse a STEP product model that corresponds to the EXPRESS information model for which it was created.

By adding back-end modules to the above software programs, translators that convert STEP data into various format can be developed. This mechanism was used in the development of the translator below.

3.3 STEP/Pattern Information Model Translator

A translator is a primary mechanism to enable data sharing between CAD/CAM systems. Using a neutral data format, a translator first converts data from the source system into the neutral format and then into the format of the destination system.

By extending NIST's STEP software tools, researchers at NIST and Georgia Institute of Technology have recently developed a translator to demonstrate the prototype implementation of the Pattern Information Model. The translator parses a STEP exchange file that has been generated from the Pattern Information Model into a working form or an in-memory representation, and then outputs a data file in an ANSI/AAMA-292 format. Both the STEP exchange file format and ANSI/AAMA-292 format are briefly described as follows:

The exchange medium for the EXPRESS information models is the STEP exchange file. A STEP exchange (or physical) file contains instances of the various entities defined by the Express information model. The STEP exchange structure format and the mapping from Express to the exchange structure described in "ISO 10303-21: 1994(E) Implementation Methods - Clear Text Encoding." The exchange structure shall be a sequential file using a clear text encoding. It consists of two sections: the header section that provides data relating to the exchange structure itself, and the data section that provides the data to be transferred. These sections may contain one or many entities. An entity consists of attributes; each attribute is a fact (datum) about an entity.

The ANSI/AAMA-292 format is a pattern data interchange standard developed by AAMA. The standard is based on the AutoCAD Version 11 DXF (drawing interchange) file format. The DXF format is in the public domain. A number of major CAD/CAM vendors have used the format to describe 2D and 3D parts. A DXF file is formatted as a standard ASCII text file, it consists of header, tables, blocks, and entities sections. Fourteen layers were defined in the standard to represent specific types of apparel pattern information.

3.4 Prototype Implementation

Two sample garments, an army shirt and a pair of BDU trousers, were selected to be used in the prototype implementation of data sharing using the Pattern Information Model. Patterns of both garments were originally provided with data files in the DXF or ANSI/AAMA-292 format. This prototype implementation was a Level 1 implementation.

The Data Probe Tool was used to populate data files corresponding to the Pattern Information Model. Several NIST's software libraries were used to create a new Data Probe. The creation of a Data Probe executable included three major steps: read in the Pattern Information Model, compile and link the model, and output a new Data Probe. With the Pattern Data Probe executable, entities defined in the sample files were manually entered, thus, the STEP exchange files of two sample garments' patterns were generated.

The STEP/Pattern Information Model translator (refer section 3.3) has been used to demonstrate the data sharing. Two STEP exchange files that were generated by the Pattern Data Probe served as input files to the translator. The translator then produced two new DXF files.

Both the original DXF files and newly generated DXF files were read into an AutoCAD system for creating pattern drawings. These drawings were compared piece by piece with the original pattern. It was found that all geometries were well captured and text information (piece names, grading points identifications, etc.,) were presented, however, the text information might be relocated in many cases. Those text information on the drawings were served as remarks; the locations of the text are actually not significant.

The EXPRESS information model provides the capability to transfer the delta-grading rule, the most common grading method. However, the ANSI/AAMA-292 format does not define how to transfer grading information, it uses a grading rule identification to refer to information that is presented elsewhere. In the above prototype implementation, the grade rule issue did not occur due to both of the original files containing only one size garment and no grade rule was presented. If the STEP exchange file contains the grade rule growth values, the grading information will be lost when a corresponding DXF file is generated using the translator. The AAMA is considering developing another standard to deal with the grading rules.

4 CONCLUSION

The American Apparel Manufacturers Association has published the ANSI/AAMA-292 Pattern Data Interchange Standard. The standard was developed by building apparel conventions into the AutoDesk's AutoCAD DXF file format. It should be noticed that the specification of the DXF file is not an official standard; it is under the auspices of AutoDesk, and therefore could be changed or extended. The ANSI/AAMA-292 can be served as an interim solution for the representation of apparel patterns, it is certainly not a long-term solution for pattern data exchange.

This report describes the approach being taken by NIST in developing a neutral format for exchanging apparel product data. An information model based on the emerging Standard for the

Exchange of Product Data (STEP) has been developed. Prototype implementation of the model has been demonstrated using two military garments. The demonstration has shown that the information model is capable of capturing the same information that can be expressed in another industry format.

Now that the initial set of STEP specifications has been approved as an International Standard, apparel manufacturers can take advantage of work done in STEP to reap the benefits of standardized apparel product data representation. An essential step is to obtain industry support and active participation by the apparel industry towards a STEP standard. The information model presented in this report can be used as the initial proposal for developing official STEP specification for apparel. The process for developing an official specification, in full conformance with STEP standard, is described in "Guidelines for the development and approval of STEP application protocols, Version 1.1," prepared by the ISO standard subcommittee, TC184/SC4. The information model can also be extended to include all the information necessary for an apparel product throughout its development life cycle.

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