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AN EVALUATION MECHANISM FOR DEFINING GAPS AND OVERLAPS OF PRODUCT INFORMATION EXCHANGE STANDARDS

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ABSTRACT

The need to exchange information between organizations or departments of the same corporation is hampered by interoperability problems that mostly originate from the necessity to comply with diverse standards while using dissimilar applications. Each organization generally uses different standards (both local and international) for products which they produce or use. The differences and similarities of these standards, or gaps and overlaps between these standards create problems when exchanging product information through the product life cycle. Defining gaps and overlaps for these standards will help us better understand the interoperability issues. This will aid in the development of strategies for reducing interoperability problems, thus improving efficient information exchange. In this study, we present different approaches for comparing standards and for identifying gaps and overlaps in standards. A Matrix--based evaluation mechanism developed for this purpose is also described.

1. INTRODUCTION

There are many different organizations and service providers working together in a company's supply chain. These organizations need to exchange information efficiently and flawlessly. The necessity of exchanging appropriate product information efficiently between different organizations throughout the product lifecycle is important and vital to reduce costs. It also helps improve quality and reduce cycle time. One of the major problems with interoperability is the use of multiple standards in the different phases of the product lifecycle by the vendors in the supply chain. The differences and similarities (gaps and overlaps) in terminologies and descriptions (including methodologies) between the standards are confusing and, hence, create problems. Identification and rectification of these gaps and overlaps in standards have become critical to reduce conflicts in the product life cycle activities.

In this study, a matrix-based evaluation mechanism has been developed to compare standards and to identify the gaps and overlaps between them. Two application protocols (APs), AP203: Configuration Controlled 3D Designs of Mechanical Parts and Assemblies and AP214: Core Data for Automotive Mechanical Design Processes [1; 2] of the ISO 10303 Standard for the Exchange of Product model data (STEP [3]) have been used intensively in the industry for similar applications to exchange data. The main motivation for this paper is to understand a better way of selecting a standard based on a required functionality. To select any standard we first need to understand the scope and functionalities required for specific needs. Unfortunately current STEP practices do not provide a good mechanism for selecting a standard. But before designing a selection mechanism we first need to compare the standards. In an effort to understand this, in this paper we analyze these two APs to understand the overlaps and gaps of standards. For the purpose of this paper, we do not consider the integration methods used by STEP standards developers to promote AP interoperability. Instead we adopt the point of view of someone interested in using STEP but not involved with AP development process and who is unfamiliar with ISO's procedures.

2. REVIEWS

Gap analysis, in general, has been widely used in business and economic studies. It is generally used to compare the actual performance with the potential performance of a company. This helps provide the company with an insight into areas that have room for improvement. The gap analysis process involves determining, documenting and approving the variance between business requirements and current capabilities. Basically, gap analysis consists of defining targets and the current position. Then, the actions to reach the targets are defined. This method is a good tool for business and economics to define gaps and to reach the targets but not applicable for comparing standards. Methods based on classification theories that have been widely used at libraries to classify books have been investigated as well. However, those methods are also not very effective unless the information contents of standards are already organized and classified in the same fashion. Subrahmanian et al [4] discuss developing a typology of standards and convergence of these standards in support of Product Lifecycle Management (PLM).

Matrix-based tables have been used extensively to make basic comparisons almost everywhere. The basic idea here is to arrange the items to be compared on the first row and the comparison parameters on the first column or vice versa. A checkmark is placed for each intersection with the compared item and the parameter wherever a comparison is met. In this paper, we will further develop this idea for our evaluation mechanism.

3. COMPARISON OF THE TWO STANDARDS: AP203 AND AP214

In order to carry out a comparison, we have studied two standards: AP203 and AP214. Both AP203 and AP214 standards exchange: 1) mechanical parts and assemblies data, 2) product definition data and configuration control data, and 3) data related to the design change. Both AP203 and AP214 include the following set of information: different representations of the data by other disciplines; specifications for design, identification of standard parts, the tracking data of a design release, design approval, design aspect or configuration control aspect of a product, supplier data of the product or the design, contract data if any, the identification of the security classification of product, and analysis or test data which is used for a design change. Unlike AP203, in addition to these specifications, AP214 also includes process plan information, tolerance data, surface condition, properties of parts and tools, simulation data of kinematics structures, references to product documentation represented in a form or format other than that specified by ISO 10303, and explicit and associative drafting of product documentation. However, note that AP203 ed2 has tolerance information [5].

Both AP203 and AP214 have the same types of representation for shape. Both use wireframe representation, faceted-boundary representation, boundary representation, and manifold surface representation. In addition to this, AP214 also has constructive solid geometry (CSG) representation.

Figure 1 depicts the common specifications within the scope of AP203 and AP214 in a Venn diagram. There are some other data exchange specifications which are not in any of these two standards. Although Figure 1 gives the impression that AP203 and AP214 are similar, note that AP214 includes tolerance, surface property, kinematics simulation and process planning data in addition to AP203. The representation types used by the two APs are also given in Figure 1. The difference in representation types between the two APs is that AP214 also supports the CSG representation in addition to B-Rep.

Figure 1 is only a starting point and it is not possible to fully capture or compare the gaps and overlaps in detail. The figure does show the existence of overlaps that need further analysis. The next section presents an alternate way we investigated to extract additional information.

4. EVALUATION TABLE TO COMPARE STANDARDS

Comparison of standards to identify gaps/overlaps is not easy. Each standard has several levels of details depending on its informational complexity. A thorough analysis of standards at different levels namely, conceptual, design, and realization languages used in information structuring and architectural differences has to be performed. Subrahmanian et al [4] defines the typology of standards as standards for architectural frameworks, content standards, information modeling standards, ontology standards, information exchange standards, visualization standards, and access and exchange rights standards. With respect to this typology we attempt to make a comparison of the architecture of the standards. As a first step, these standards have to be broken down into details for comparison purposes. The comparison should also give a numerical value to show the similarities. Hence, an effective evaluation mechanism is needed to meet these requirements.

With the above issues in mind we developed an evaluation table to compare the standards. In this evaluation table (see Table 1), rows consist of requirements or terms of the standards. Columns consist of the standards to be compared. Different phases of Product Life Cycle (PLC) are represented as “Product lifecycle phases” in column one.

For different lifecycle phases, there are different requirements. If a standard defines a requirement, “1” will be assigned for this requirement under this column (Table 1). If it does not define that requirement, then a “0” will be assigned. After filling in all zeros and ones, the two columns are added and the result is presented on the right – the “Sum” column. In the “Sum” column, if it is 0, neither of the standards will have that property. This means they are similar and both do not represent the particular requirement in that row. If it is 1, one of the standards has that property and this means there is a gap between these two standards for that property. If it is 2, both of the standards will have that property. This means they are similar and there is an overlap.

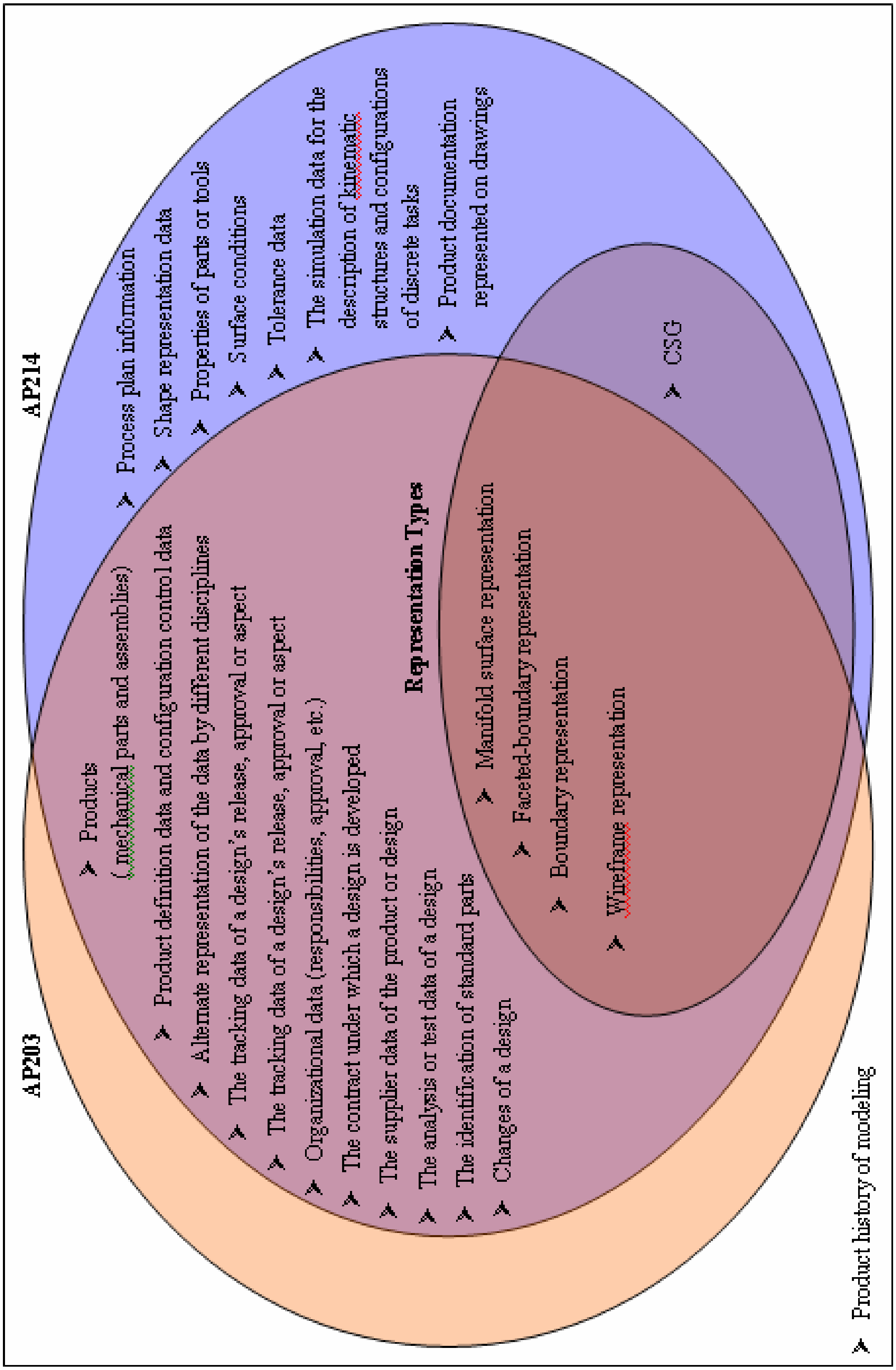

Figure 1. The comparison of AP203 and AP214

Table 1. Sample Evaluation Table

Gap and Overlap Evaluation Table				
	Std1	Std2	Sum	Comment
Product Lifecycle Phase				
Requir. A	0	0	0	0 means they both don't have the requirement and in that sense they are similar.
Requir. B	0	1	1	Neither 0 nor 2 means there is a gap. At least one of the standards has this requirement.
Requir. C	1	0	1	
Requir. D	1	1	2	2 means there is an overlap.

To extend this evaluation over PLC for comparing different standards, we have to define the PLC phases and requirements i.e., we have to define the terminology in PLC to compare standards. Standards have different terminologies and descriptions and hence it is difficult to compare. They either use different terms to define the same thing or conceptualize the different things using similar terminologies. In Table 2 we we have attempted to create the terms required for a data exchange standard through the PLC. The terms in column 1 of Table 2 are extracted from the standards AP203, AP214, GEIA927 and EIA836. EIA836 is an Electronic Industries Alliance (EIA) standard [6] for configuration management data exchange and interoperability. GEIA927 is the Government Electronics and Information Technology Association (GEIA) standard [7]. It has been developed to support a "Common Data Schema for Complex Systems." The reason for including GEIA927 and EIA836 is to broaden our comparison beyond what is defined in AP203 and AP214. For this paper we are not including these GEIA standards for comparison. We have concentrated only on the comparison of two ISO 10303 standards AP203 and AP214, because they address the same life cycle phases whereas the EIA standards also address other phases of PLC. In the next section, we present the evaluation table to compare two standards: AP203 1st Ed. and AP214.

An evaluation table can be successful only if the associated terminology can be developed for the standards to be compared. However, this means related terms have to be defined each time when a different standard is compared. This could be overwhelming when comparing standards in different application areas. A formal detailed analysis ontology is needed to define common terminology and the relationships between terminologies.

4.1. CASE STUDY: COMPARING AP203 1ST ED. AND AP214 USING THE EVALUATION TABLE

In this section we applied our evaluation mechanism to compare the two standards: AP203 1st Ed. and AP214. After filling out the necessary 1s and 0s in the table, the two columns for AP203 1st Ed. and AP214 were added. The result is written to the "Sum" column. The next column presents the comments. Each comment has been explained in detail at the end of the table. Due to page limits on this paper, we only

Table 2. Evaluation table for standards through product lifecycle

Product Life Cycle Phases	Std 1	Std 2	Sum	Comment
CONCEIVE				
Product requirements				
Product specifications				
DESIGN				
Product				
Product definition				
Configuration control				
Design change				
Physically realized parts				
Shape representation				
2D Wireframe w/o topology				
3D Wireframe w/o topology				
Surface w/o topology				
2DWireframe w/ topology				
3DWireframe w/ topology				
Manifold surfaces w/ topology				
Faceted boundary rep.				
B-rep				
Geometrically bounded surface rep.				
CSG				
Compound shape rep.				
Feature representation				
Visual representation				
Surface conditions				
Dimensioning				
Geometrical tolerance				
Parametric representation				
Alternate representations				
Specifications by designer				
Standard parts				
Design release				
Supplier				
Contract				
Security				
Analysis				
Simulation data				
Continuous simulation				
Test				
Properties of parts/tools				
REALIZE				
Process plan				
Documentation				
Pneumatic function				
Hydraulic function				
Electric function				
Electronic function				
Management				
Marketing				
SERVICE				
Operation				
Maintenance				
Recycling				

present part of the results i.e., "Shape representation" under the domain "DESIGN" defined earlier in Table 2. Also, we included only a few representative comments at the end of Table 3.

Table 3. Comparison of standards AP203 1st Ed. and AP214 by using an evaluation table

Product Life Cycle Phases	AP203	AP214	Sum	Comment
DESIGN				
Shape representation				
2D Wireframe w/o topology	1	1	2	c1
3D Wireframe w/o topology	1	1	2	c1
Surface w/o topology	1	0	1	c2
2DWireframe w/ topology	1	0	1	c3
3DWireframe w/ topology	1	0	1	c3
Manifold surfaces w/ topology	1	1	2	c4
Faceted boundary rep.	1	1	2	c5
B-rep	1	1	2	c6
Geometrically bounded surface rep.	0	1	1	c7
CSG	0	1	1	c8
Compound shape rep.	0	1	1	c9

Comments for Table 3:

c6 - AP203 1st Ed. uses Advanced B-rep to represent shapes whereas AP214 uses Faceted B-rep. Although both use B-rep there are underlying differences.

c8 - AP214 can also represent solid models using CSG whereas AP203 1st Ed. cannot. CSG shape is a CSG tree made of primitives by applying Boolean operations.

c9 - AP214 can represent models using compound shape representation method whereas AP203 1st Ed. cannot. Compound shape representation is a type of shape representation that represents the shape or a portion of the shape of a product using elements of different dimensionality such as wireframes or surface models that are topologically connected. Hence, AP214 is more advantageous for compound shape representation

5. CONTENT ANALYSIS OF AP203 AND AP214

Comparing scope of standards in Venn diagrams or evaluation tables, as presented in the previous sections, are not sufficient in giving details of the comparison because most of the details are hidden. For this reason, we attempted a preliminary statistics study of the following schemas and items in STEP: Application Activity Models (AAM), which are a set of activities that help in understanding the scope and information requirements defined in the application protocols; Application Reference Models (ARM), which describe the information requirements and constraints of a specific application context; Application Objects, which define the elements in ARM diagrams; Units of Functionality (UoF), which show organized relationships between elements in the ARM diagram; Application Assertions that specify the relationships between application objects, the cardinality of the relationships, and the rules required for the integrity and validity of the application objects and UoFs; and Application Interpreted Models (AIM), which are implementable schemas that use the integrated resources necessary to satisfy the information requirements and constraints of an application reference model. A core set of abstract models of various aspects of product model information (including geometry and Product Data Management [PDM] information) is called the integrated resources

Units of functionalities (UoF), application objects, and application assertions will be compared first. In AP203, there are 14 UoFs, 41 application objects, and 39 application assertions. In AP214, there are 31 UoFs, 565 application objects and 1701 application assertions. The numbers of related models, UoFs, application objects and application assertions are presented in Table 4.

It is also important to note that AP203 has only two AAM models whereas AP214 has eight AAM models. Also, the models are different. Hence the comparison could not be done via AAM models of APs.

ARMs, reference models, were considered next. AP203 ARMs are represented in IDEF1X [8] and there are 7 of them. EXPRESS-G [9] schemas are used for AP214 ARMs and there are 89 of them. Since these models have different representation schemas, they need to be mapped.

AIMs -- representation of reference models in EXPRESS-G -- are considered next. There are 39 EXPRESS-G schemas given for AIMs in AP203 whereas there are 137 of them in AP214. All these data are shown in Table 4.

Table 4. Comparison in numbers

Comparison parameters	Number of specified information types	
	AP203	**AP214**
UoF	14	31
Application Objects	41	565
Application Assertions	39	1701
AAM	2	8
ARM	7	89
AIM	39	137

After this preliminary comparison, we realized the need to compare at the schema level. Hence we proceeded to look at structural differences and compared the AIM diagrams. The "product definition" AIMs in EXPRESS-G for both AP203 and AP214 are shown in Figure 2 and Figure 3, respectively. Comparing these two figures gives the following results:

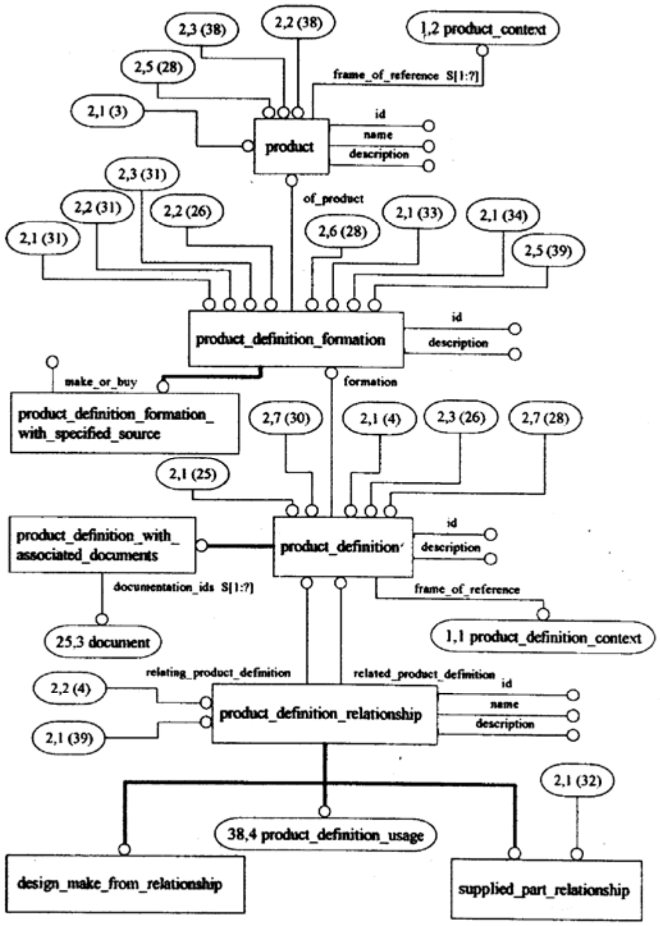

Figure 2. Product definition – AP203's AIM EXPRESS-G diagram [1]

- Both define "product" entity with attributes id, name, description and they also have a relationship with "product_context" and "product_definition_formation". The first one is "frame_of_reference". It is a set relation from one to one or many. The second one is formation.
- Both define "product_definition_formation" entity with attributes id and description. They have a relationship with "product_definition" and it is "formation".
- In both APs, "product_definition_formation_with_specified_source" is a subset of "product_definition_formation".
- After "product_definition" entity in EXPRESS-G schemas two APs differ a lot. "product_definition" is the superset of "product_definition_with_associated_documents" in AP203 whereas it is the superset of also "product_definition_resource" in AP214. In AP214, "product_definition_with_associated_documents" has a subset, "physically_modeled_product_definition" whereas in AP203 it doesn't have any subset. In AP214, "product_definition" entity has extra relations.

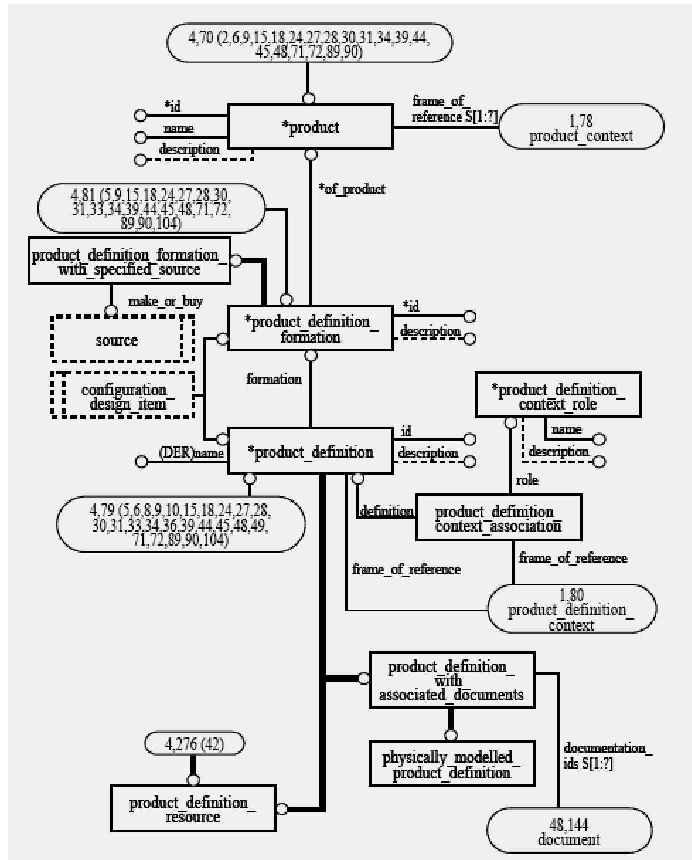

Figure 3. Product definition – AP214's AIM EXPRESS-G diagram [2]

Comparing EXPRESS-G schemas also did not yield useful results. Hence, our next step would be to compare EXPRESS (ASCII) models of AIM. However, an appropriate reasoning technique may be needed to achieve a successful comparison. We are presently exploring several techniques including converting these EXPRESS models to Web Ontology Language (OWL) [10] and utilize reasoning and inference engines as reported in [11].

6. CONCLUSION

In this paper, we have presented different ways to compare standards and to identify the gaps and overlaps of standards. Since there exist numerous standards for different product life cycle phases, repetition or lack of important information among those standards is very likely. This causes major confusion and it is a bottleneck during information exchange. An efficient gap and overlap detection technique may help reduce this problem. We developed a matrix-based evaluation technique as a first step to address these issues. However, a content-based comparison procedure is needed to find out gaps and overlaps fully. As part of our future work, we will consider extending our proposed method into a complete ontology-based evaluation mechanism which will incorporate a reason-based context analysis tool along with the evaluation table as mentioned in the paper.

7. ACKNOWLEDGEMENT

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9. REFERENCES

1. ISO 10303-203: 1994, Product Data Representation and exchange - AP 203: Configuration controlled 3D design of mechanical parts and assemblies. International Organization for Standardization (ISO), Geneva, Switzerland.

2. Industrial automation systems and integration -- Product data representation and exchange -- Part 214: Application protocol: Core data for automotive mechanical design processes. 2003. International Organization for Standardization (ISO), Geneva, Switzerland.

3. Kemmerer, S., "STEP: The Grand Experience, (Editor)," NIST Special Publication 939, National Institute of Standards and Technology, Gaithersburg, MD 20899, USA, 1999.

4. Sudarsan, R., Subrahmainain, E., Bouras, A., Fenves, S. J., Foufou, S., and Sriram, R. D., "The role of standards in product lifecycle management support," Inderscience Enterprises Limited,2006.

5. Briggs, D., and Hendrix, T.. AP203 Edition 2, Configuration Controlled 3D Design of Mechanical Parts and Assemblies. http://www.isd.mel.nist.gov/projects/metrology_interoperability/imis/presentations/Hendrix.pdf . 3-28-0006. Boeing Technology.

6. EIA, "EIA-836: Configuration Management Data Exchange and Interoperability. Draft Version 1.2," Jan. 2004.

7. Colson, J.. GEIA-927 Standard Common Data Schema for Complex Systems. http://www.ndia.org/Content/ContentGroups/Divisions1/Systems_Engineering/PDFs18/Modeling_Committee_PDFs/Colson_John.pdf . 2006.

8. IDEF1X. http://www.idef.com/IDEF1X.html . 2007.

9. Schenck, D., and Wilson, P. R., *Information modeling: the EXPRESS way*, Oxford University Press, New York,1994.

10. Web Ontology Language (OWL). http://www.w3.org/2004/OWL/ . 2005.

11. Fiorentini, X., Gambino, I., Liang, V., Foufou, S., Sudarsan Rachuri, Bock, C., and Mahesh, M., "Towards an ontology for open assembly model,"2007, pp. 445-456.