Software Parts Classification for Agile and Efficient Product Life Cycle Management

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Abstract. The proliferation of software components and embedded systems in bundling of smart and innovative products and services has augmented the need of software classification in manufacturing context. Existing software classification standards are limited to information technology, networking, and mobile applications. To gain efficiency in product development through reusability and reduction in search and retrieval time for multi domain part structure development; software classification is imperative.

This paper discusses the different classification and nomenclature systems available for software, its benefits in Product Lifecycle Management (PLM) and other business areas, as well as limitation of existing PLM applications. This paper explains a novel, and contextual framework for classification of software components to enable strategic cataloguing for improved traceability, reusability, and Bill of Materials (BOM) management.

Keywords: Software part · Software part classification · Classification framework · Software classification standards · Classification for ALM

1 Introduction

Traditional business drivers are no longer sufficient to provide sustainability and growth to an organization. Globalization, pricing pressure, product complexity and competition are new drivers demanding organizations to substitute part of their existing portfolios with innovative products. Burgeoning of embedded systems in products to make it smarter, complaint with new regulatory requirements and experiential offerings for customers have raised the bar [1, 2]. Embedded software market is estimated to grow with CAGR of 7% and would create a value of more than $20 billion by 2027 [3]. Surge in its demand is being seen more in automotive industry due to increased regulatory pressure and advanced features requirements, and in healthcare industry due to COVID-19

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impact. PLM applications provide capabilities to define firmware and software as a part and features to link with their executables. But these are not sufficient for manufacturers who are looking to classify their software and firmware parts like hardware parts. There are international standards like UNSPC[1], ECLASS[2], GPC[3], CPV[4], ETIM[5] etc. which provide taxonomy for products and services [4, 5]. These standards are highly skewed towards the classification of hardware components. Adopting the current standard of four level hierarchical classification structure is not a fool-proof solution since hardware part can have one to many relationships with the corresponding software parts. Multiple relationships exist due to different supplier, versions, and specific features of the software. This paper covers investigation and analysis on existing global classification standards and has proposed a structured approach for software part classification.

Development of new software classifications standards and harmonized meta data attribute definition will significantly reduce search retrieval time, improve correctness, reliability, reusability and traceability and ease trade across countries [6–8]. For instance, when a designer is looking for a software component to meet a new product specification, the classification attributes would help to narrow down search and give relevant information from large repository of data. This would also help to avoid creation of duplicate parts. In another scenario, a field engineer would be able to reduce root cause analysis time and identify similar components when a warranty claim is reported.

2 Classification System

In this digital age, for a company to stay relevant and survive, depends on rate of innovation and its introduction through complex supply chain web [9]. Classification is essential to businesses to improve supplier sourcing strategy, optimize productions, for targeting buyers and reduce business transactions time.

Classification means logical grouping and ordering of large and expanding range of commodity types according to common characteristics. Existing international standards vary in terms of objectives, data model, granularity, breadth of category and adoption with respective to the region and refer Sect. 3 for more details. In general, all classification standards provide coded name, identification number and textual description in noun-modifier combination with different schema. Variety of part types, for example, hardware, electrical, mechanical, software etc. are categorized at different levels. The bar graph given in Fig. 1. shows distribution of categories of software parts at multiple hierarchy levels by 4 popular international standards.

[1] United Nations Standard Products and Services Code.

[2] ECLASS is a cross-industry product-data standard for the classification and unique description of products and services.

[3] Global Product Classification.

[4] Common Procurement Vocabulary.

[5] European Technical Information Model.

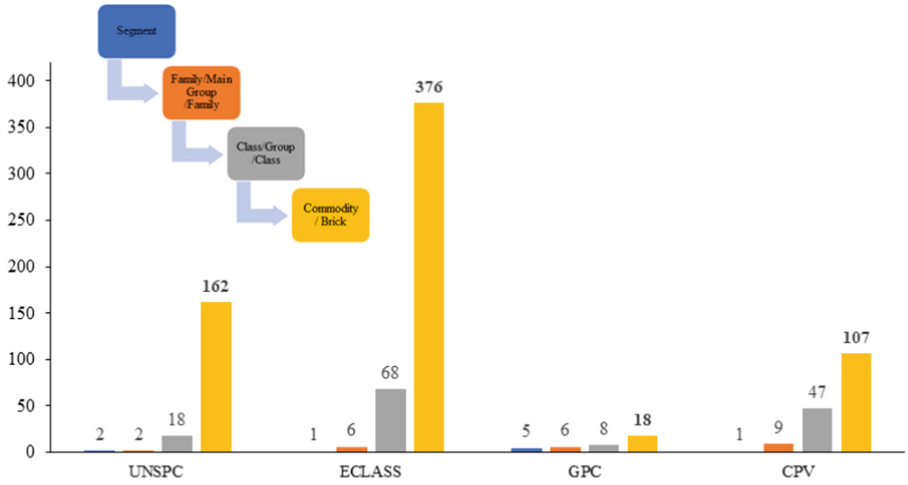

Fig. 1. Software classes at different levels for 4 global classification standards (Data is compiled from the codeset of each of the mentioned global standards).

2.1 Need for Software Classification System and Standardized Data

Business discontinuity due to COVID-19 has accelerated the process to have virtual collaborative environment to take design decisions quickly and need of IT systems with robust integrated data management capabilities. Design specific decisions get delayed due to variability in product data model definition and schema across enterprise level systems like PLM, ERP[6], MES[7], CRM[8] and SCM[9]. Uniform, classified & unambiguous data definition form the backbone of any enterprise-wide digital initiative. Manufacturing companies are looking for implementation of international standards for classification of different part types because proprietary standard of classification restricts an organization to collaborate with suppliers, partners, dealers, and retailers.

Available international standards do not fully define and classify different software parts created by R&D. On average, only 1% of total product classes (bottom of the hierarchy) are defined for software parts as shown in Fig. 2.

They provide rich taxonomy and attribute definition for electronic, hardware, electric and mechanical part types but not for software part types. Existing PLM systems only offer association between different part types as shown in an illustration (refer Fig. 3).

[6] Enterprise Resource Planning.
[7] Manufacturing Execution System.
[8] Customer Relationship Management.
[9] Supply Chain Management.

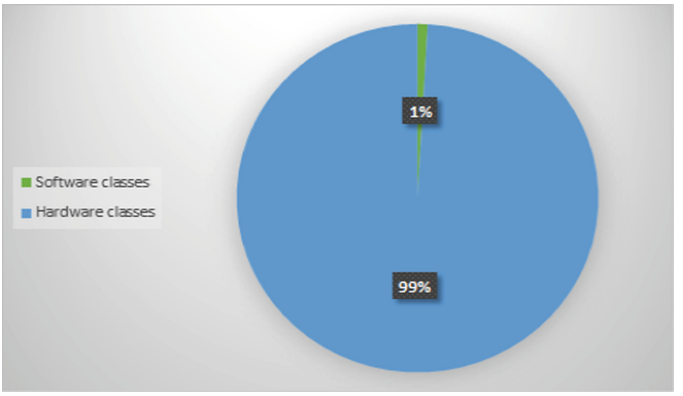

Fig. 2. Consolidated software vs hardware classes in current standards.

Only association feature of PLM system is not enough to fulfill the needs of engineering departments and associated areas. There is considerable dearth of software data definition and classification. More and more companies are adopting ALM[10]-PLM integration to strengthen the new product development to reduce time to market but its full potential is not being realized in the absence of standardized software attributes and taxonomy. In current scenario, software data is fragmented and residing in multiple systems with inaccurate, incomplete, and inconsistent information. So, it is imperative to have well-defined classification and nomenclature system for software and its adoption into extended enterprise systems.

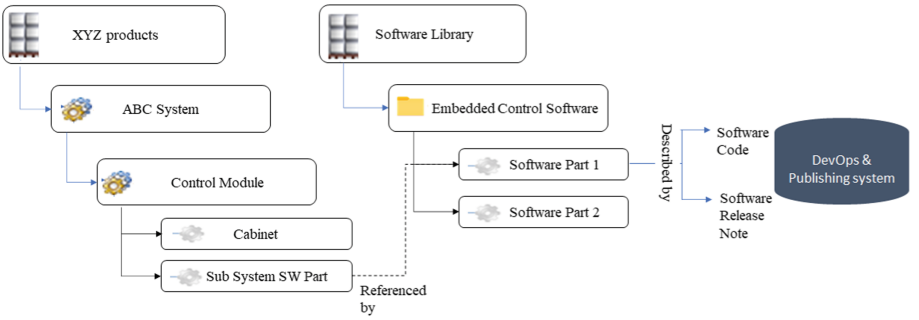

Fig. 3. Illustrative diagram showing software part type relationship with hardware part types.

2.2 Benefits of Classification System

Uniform, standard, and common engineering language for product characteristics has significant impact on metrices like engineering hours, procurement time, material costs

[10] Application Lifecycle Management.

etc. with error free data and less time-consuming processes [10, 11]. It declutters the process for searching of information from different solution providers, catalogues, on internet, by data conversion, and users from different field of engineering. Especially, software classification in digital era in context to hardware will significantly boost mass personalization and enhanced traceability and reuse-based software development [12].

3 Analysis of Existing International Standards

Table 1 shows the comparison of top 5 international standards categorizing software components at different levels, and it could act as reference map and further populated

Table 1. Eleven Criteria comparison of international classification standards

Criteria	ECLASS	UNSPC	GPC	CPV	ETIM
Standard Objective	Empower procurement, sales, engineering	Procurement	Buyers & manufacturers in cataloguing	Public procurement	Taxonomic classification of technical products
Classification or Product data dictionary	Product data dictionary	Classification	Product data dictionary	Classification	Product data dictionary
Schema (Classification level)	Four	Four	Four	Five	Two
Applicable Industry	Multi sector e.g., Automotive, construction, Electrical, Textile etc.	Multi sector e.g., electronic, Oil, Software, Energy, Healthcare etc.	Specific sectors such as apparel, consumer goods, etc.	Specific sectors e.g., Raw material, tourism, toys, Biotechnology, etc.	Specific sectors such as Electrotechnical, plumbing, shipbuilding etc.
Semantic definition and Attributes or feature availability	Partially available but rich in attributes	Not available	Available but number of attributes less compared to ECLASS	Not available	Partially available but rich in attributes
Language support	16	15	25	24	17
Geographic dominance	Germany & other European countries	US, Asia, Australia	Global	European countries	European countries
Adoption by companies	4000 +	2100 +	20L+	2.5L +	300+
Industry 4.0 (Digital Twin)	Provide library for machine readable characteristics	No references found	No references found	No references found	No references found
R&D specific features	ECLASS ADVANCED is mainly used in engineering and CAx areas.	No references found	No references found	No references found	Characteristics for 3D product data & Building information management
Licenses	Required	Free	Required	Required	Free

with more contextual criteria. Few standards like UNSPC are more focused on categorization of products and services rather than defining properties and associated values and units.

3.1 Classification Schematic Comparison for Software

ECLASS classification standard provides more software classes compared to other global standards (as mentioned in Sect. 2), but it lacks in quality and quantity as well. Newness in the name of software classes is created by appending information in parentheses signals lack of due diligence. Figure 4 elucidates variation in nomenclature and variety of category at different levels of software part classification schema.

Grouping of software are generic and based on how they are used instead of what they are. For example, nomenclature of software is based on application areas like telecommunication devices, office applications, engineering applications etc. There is a lack in variety, associated definition, and redundancy of software characteristics. The repetition of similar attributes also makes difficult to distinguish two disparate classes.

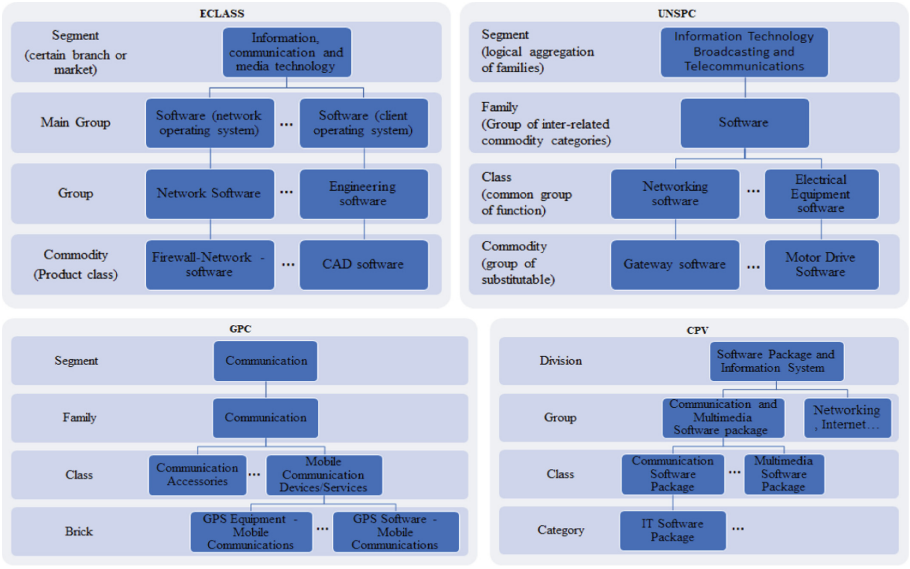

Fig. 4. Classification schema across global standards

4 Framework for Software Part Classification

Limitation posed by existing international standards urges for further exploration for new approaches to categorize software components. This necessity triggers pertinent questions as mentioned below:

- Are business needs for classification of hardware and software components same?
- What should be the approach? Should it be like current approaches of HW classification; and clustering software components in the same group of HW components?
- How should an organization classify software components? Should it adopt one international standard or custom approach to best serve the organization need?
- What should be the classification schema? Multi hierarchy vs flat taxonomy structure needs to be investigated.

The structured approach discussed in this section is based on our experience in implementation of software part classifications projects and can be guide for an organization to establish center of excellence for software part classification and disseminating knowledge across virtually integrated value chain. The success of enterprise-wide program depends upon strong governance structure and adoption of industry best practices for execution [13]. Setting up vision in line with organization objectives, audit frequency, hierarchical data governance structure and standardized business processes are key enablers for sustenance of such program. Framework shown in Fig. 5 presents end to end view of contextual approach with necessary processes, concepts, and tools for digital journey of software parts classification and their standardized data definition.

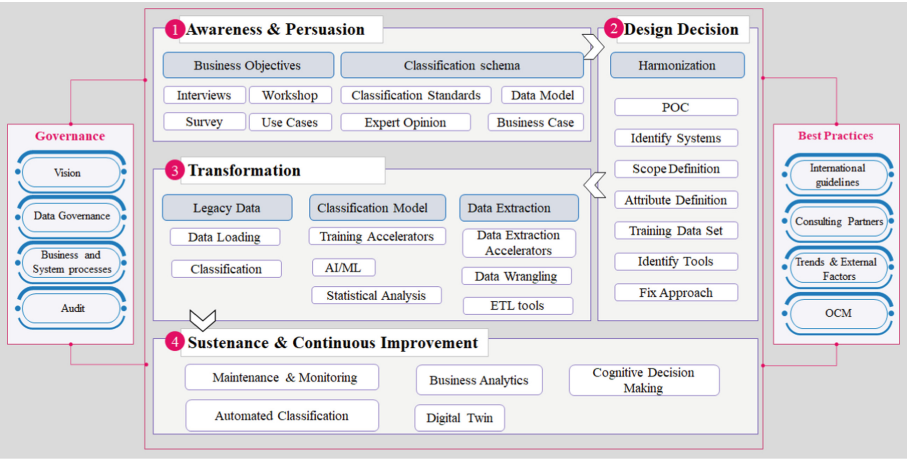

Fig. 5. Proposed framework for software part classification

4.1 Awareness and Persuasion

The digital journey of classification starts with dissemination of knowledge within enterprise and suppliers to create awareness. The potential adopters who could be at any level in their organization and acquired information from various communication channels. They should first enrich themselves with knowledge from primary and secondary research. Good understanding of the business use cases is essential to highlight the benefits and values that classification brings to the table.

The next step is by persuasion of top management or steering committee to approve business case for designing and implementation of standard coding & taxonomy system for products and services. A strong business case is prerequisite for buy-in from top management. Partnering with right consulting services to conduct interviews, workshops, and survey can trigger learning environment for employees to assimilate knowledge about global nomenclature and classification systems and will expedite overall implementation program. In depth, due diligence by evaluating pros and cons of existing schema with respect to various global schemas will be beneficial. Understanding existing internal processes and data model and analyzing it carefully with the support of experts are required to come up with multiple evaluation criteria. Identify industry best practices and latest trends while defining classification hierarchy.

4.2 Design Decision

Harmonization in classification of product and services and associated attributes definition across multiple systems are critical aspects for digital transformation journey of an organization. Standard coding system leads to part data synchronization, process flow integration and data standardization across company divisions, suppliers, and global locations. Identify and define SMART[11] metrices and set the base levels to be compared after implementation of standardized classification system. Choose few metrices initially which aligns with near term goals as well as with business key performance indicators s and perform benefit appraisal just before and after implementation.

It is advisable to kick off the implementation program with PoC (Proof of Concept) to take critical design decisions before full fledge rolling out. Doing part classification project using big bang approach could be risky and may create additional stress in the system. So, it is advisable to have phased approach for design and implementation of the project. Starting with PoC in an agile way with limited data set and few divisions will help to develop methods, frameworks, tools and selection of relevant business technological solutions and IT interventions for large program execution. The aim of PoC is to generate awareness, realization of benefits and return on investment demonstration to reduce organizational frictions.

4.3 Transformation

Tools and methods identified in previous steps will be leveraged for scaled agile roll out across divisions, product groups and suppliers. In general, organization product data resides on multiple systems with unique information. IT tools for data extraction automates the process for large volume of data. Based on the type of enterprise system and the situation, it is possible to select the partial or full data model. Extracted data can't be used as it is and needs to go through data wrangling process. The next step of transformation is the classification. Manual approach using statistical methods could suffice if the volumes are low otherwise it is advisable to go for automated classification solutions with quality assurance checks. Artificial Intelligence (AI) based automated classification approach involves training, tuning, model selection and testing using different types of

[11] Specific, Measurable, Achievable, Relevant, Time-bound.

data set. In AI based classification, predominantly, there are 2 steps. First is the fully automated classification step, where ML (Machine Learning) model parameters are generated based on the training data. Next one is the guided automation where some degree of manual intervention required for quality assurance. The final step of transformation is data loading, where classified data is updated into the enterprise systems. If consolidated item master or electronic catalogs already exists because of standardized processes and enterprise applications can skip few steps in transformation.

4.4 Sustenance and Continuous Improvement

Continuous evaluation, identification of new use cases, and automation of classification systems are necessary to stay agile, innovative, competitive and remove inefficiency in the system. To retain integrity of the data over time, regular maintenance based on the principles of information asset life cycle management is required [14]. Any modification must be reported through formal change request for analysis and evaluation by change control board of the data governance structure. Updating of existing data set or introduction of new category should follow operational guidelines of implementation. It should be open, flexible, easier to adopt and attract classification of new software-based products and services.

5 Summary

In the era of Industry 4.0, where each manufacturing company is looking to extract business value leveraging digital twins; it is imperative to have standardized product data across entire vertically integrated value chain. Harmonized product characteristics and classification not only simplify R&D processes but also streamline procurement, sales & marketing, material management and manufacturing processes. Common engineering language or semantic system facilitates automation of design works to create circuit diagrams, part lists, wiring lists, assembly diagram as well as automation of robotic manufacturing process. Since number and variety of embedded software and firmware are increasing, organization should look for new use cases to support adoption of software part classification. Each of the elements mentioned in the proposed framework needs to be adapted and contextualized as per company needs and could be utilized for classification of other part types as well.

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