STUDY ON INTEROPERABILITY PROBLEMS AMONG CAD/CAM SYSTEMS IN AUTOMOTIVE INDUSTRY

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ABSTRAK

Di dalam industri automotif, terdapat banyak sistem-sistem Rekabentuk Berbantukan Komputer (CAD) dan Pembuatan Berbantukan Komputer (CAM) yang digunakan. Setiap sistem mempunyai penafsiran data yang tersendiri. Hasilnya, data produk yang dihasilkan dan disimpan berada dalam pelbagai format yang tidak serasi dengan berbagai-bagai perisian CAD/CAM yang lain. Ini menyebabkan masalah operasi antara sistem berlaku apabila fail-fail dipindahkan dari satu sistem ke sistem yang lain. Walaupun dengan kemajuan yang telah dicapai dalam era pemindahan data antara sistem CAD/CAM ini, masalah ini masih merupakan isu yang besar. Projek ini mengkaji tentang senario masalah perpindahan data CAD/CAM khususnya dalam industri automotif di Malaysia. Dengan merujuk kepada kajian-kajian lain di Amerika Syarikat, Jerman dan Australia, satu kerangka kerja yang membantu industri automotif Malaysia menangani masalah tersebut secara proaktif dicadangkan.

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GLOSSARY OF ABBREVIATIONS

AP	Application Protocol
B-rep	Boundary Representation
CAD	Computer Aided Design
CAE	Computer Aided Engineering
CAM	Computer Aided Manufacturing
CAPP	Computer Aided Process Planning
CSG	Constructive Solid Geometry
FEA	Finite Element Analysis
IGES	Initial Graphics Exchange Specification
IRC	Internet Relay Chat
MOU	Memorandum of Understanding
MOUAC	Memorandum of Common Understanding and Cooperation
MSBO	Manifold Solid B-rep Object
NURBS	Non-Uniform Rational B-splines
OEM	Original Equipment Manufacturer
PDM	Product Data Management
PHP	PHP: Hypertext Preprocessor
SME	Small Medium Enterprise
STEP	Standard for the Exchange of Product model data
VDA	Verband der Automobilindustrie (German Association of the Automotive Industry)
XML	Extensible Markup Language

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CHAPTER 1

INTRODUCTION

1.1 Background

Automotive industries require huge complexity in design process that has been done with helps from CAD/CAM system. Data from computer-aided design, engineering, and manufacturing software systems are routinely exchanged within companies and between original equipment manufacturers (OEMs), first-tier automotive component suppliers, sub-tier automotive component suppliers, and tooling suppliers. This file exchanges includes the process of translating and transferring product data, which develop technical problems associated with these exchanges. These technical problems have therefore taken on greater importance, because they affect the cost and time required to design and manufacture an automobile. This data transfer problem is one of the problems called interoperability problems in CAD/CAM systems. Interoperability means the ability of information and communication technology (ICT) systems and of the business processes they support to exchange data and to enable sharing of information and knowledge. CAD interoperability or interoperability between CAD systems is realized when the converted model file is fully functional in the target CAD system. Full functionality involves more than just the ability to move a hole, or redefine a protruding boss. The details of how the geometry is defined must be available to the CAD application so that they can be fully analyzed and manipulated.

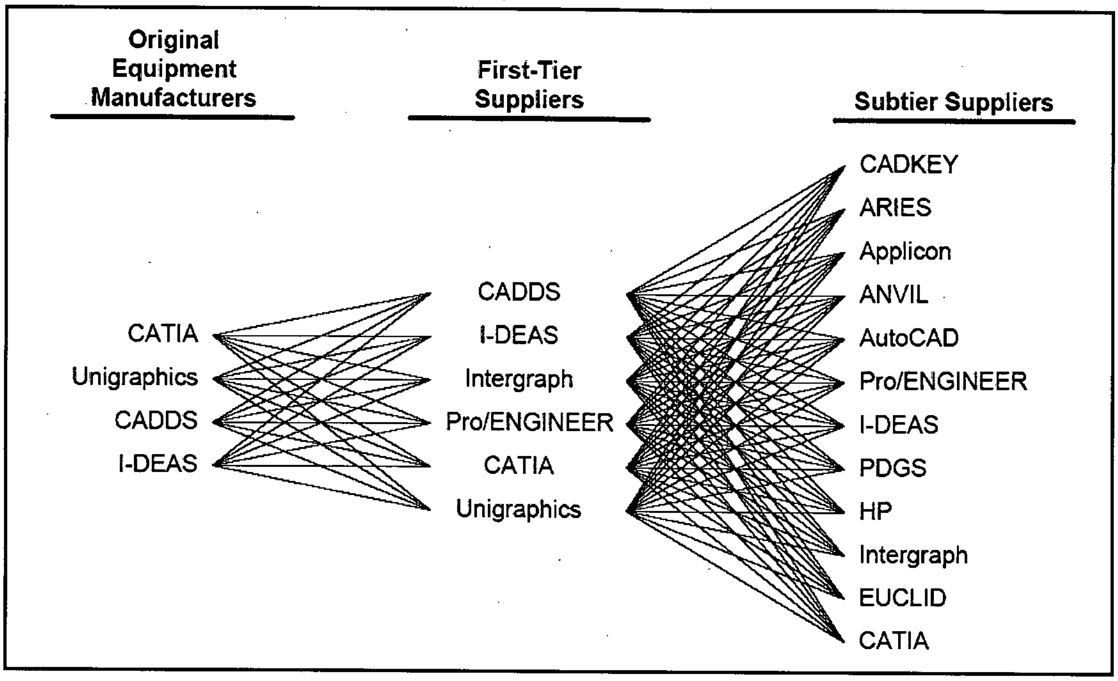

Figure 1.1: Multiple CAD/CAM Systems in the Automobile Supply Chain [1]

Figure 1.1 identifies some of the different CAD/CAM platforms currently used by members of the U.S. automobile supply chain. The figure, based on AIAG, demonstrates that a first-tier supplier with several OEM customers and subtier suppliers may have to purchase, learn, and maintain multiple, often redundant platforms or translation software. Data exchange is the totality of establishing the methodology for and the successful achievement of the transfer of data between two distinct CAD/CAM systems. Data should only be exchanged when the methodology has been proven and agreed and a data exchange agreement, even of a very simple kind, is in place.

Several studies have been done on this area in major automotive countries such as USA, Germany and Australia. This paper will study the situation in Malaysia's automotive industry which influent by two national automobile makers; Proton and Perodua. It also proposes some actions that can be taken in order to improve product data management.

1.1.1 Automotive Supply Chain

An automobile consists of several major systems; each system contains a number of components and parts. For instance, Peugeot 206 assemblies require 1820 parts in the Trim and Final Shop itself. Figure 1.2 shows an anatomy of a typical automobile.

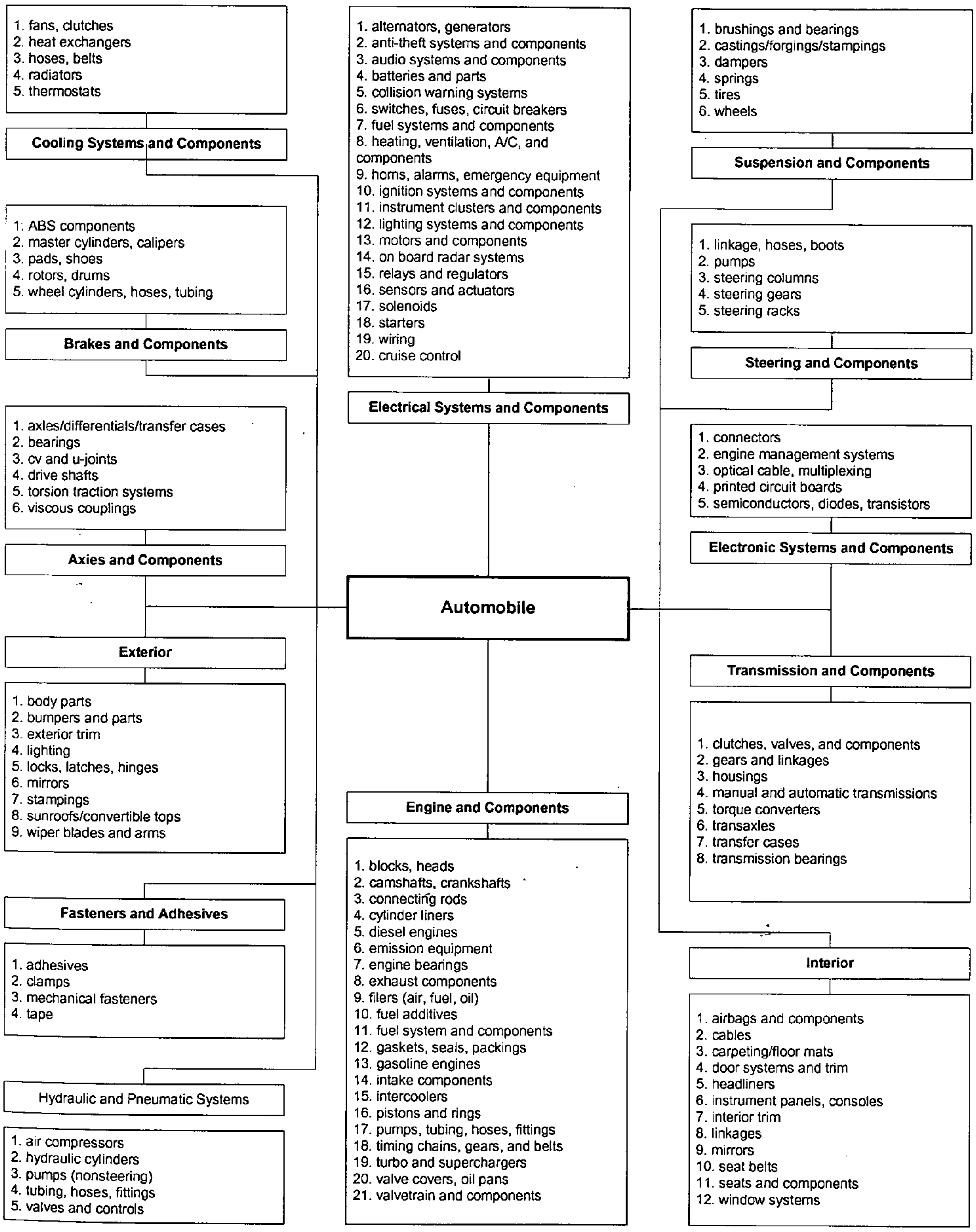

Figure 1.2: Structure of an Automobile [2]

Malaysia represents the largest automobile markets in Southeast Asia. In Malaysia's automotive industry, there are two main manufacturers of national cars, Proton and Perodua. Proton is the number one brand of car in Malaysia, where it commands a market share of roughly 70%. In 1997, there are 196 local vendors to PROTON and PERODUA. There are 38 components parts manufacturers, which are now able to export their products on their own. Out of 204 Proton vendors, 25 have been identified as tier 1 suppliers / system integrators [3].

After 7 years, there are at present 14 manufacturers / assemblers of motor vehicles, 3 composite body sports car makers, 24 franchise holders and more than 350 automotive component manufacturers. Proton and Perodua accounted for 85% of the total passenger car production volume in 2003, while Proton, Perodua, Inokom, MTB and Naza KIA together accounted for about 48% of the total commercial vehicle production volume in 2003 [4].

Amongst the components and parts manufacturers, 369 are vendors to Proton and Perodua, with 32 of the Proton vendors being tier 1 suppliers/system integrators, and the rest, tier 2 or tier 3 suppliers, supplying over 4,000 components. Most of the component manufacturers have achieved value added of 25% - 35%.

About 40 components manufacturers are presently exporting their components, such as steering wheels, rims, brake pads, wheels, bumpers, bodies, exhaust, radiators and shock absorbers. The industry as a whole continued to attract both local and foreign investments.

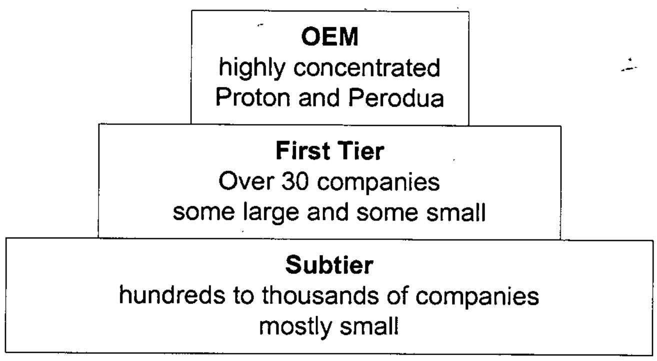

Figure 1.3: Malaysia's Automotive Supply Chain

Figure 1.3 shows the Malaysia's automotive industries supply chain. Compared to other automotive country like Germany and United Kingdom (UK), the number of companies involved in this supply chain is relatively small. This study captured the problem that encountered by the vendors according to interoperability between CAD/CAM systems.

1.1.2 CAD/CAM Usage in Automotive

CAD/CAM is defined as computer-aided design and manufacture; the use of computers to plan and make industrial products [5]. It is a system that consists of Computer Aided Design (CAD) system and Computer Aided Manufacturing (CAM) system. CAD is a tool that helps user draw, draft and design something easier and more accurate than conventional engineering drawing on paper. One of the most popular CAD software is AutoCAD which has been used widely in multi-disciplines all around the world. In the other hand, CAM is a system that helps users manufactured an electronic drawing. CAM software often connected into Computer Numerical Control (CNC) machine which will manufacture the electronic model into physical model. One of the CAM systems is MasterCAM.

CAD/CAM is a system that has both functions, it helps designers from draft process until manufacturing process. Some systems have value added function like Finite Element Analysis (FEA), Computer Aided Process Planning (CAPP), Product Data Management (PDM) and some more. This kind of feature-rich system is used in powerful industry such as aerospace & defence and automotive.

Automotive industries have recognized three high-end CAD/CAM systems that can support the development of automobile [6]. They are;-

a) CATIA from Dassault Systèmes
b) I-DEAS from Structural Dynamics Research Corp (SDRC)
c) Unigraphics from Unigraphics Solutions, Inc.

These three CAD/CAM systems have their own strength against others. According to Dave Burdick, vice president of Engineering Applications for the market research firm Gartner Group, their has five major add-on values that supersede most of CAD/CAM systems;

a) Advanced surfacing
b) Advanced solid modelling
c) The ability to handle large assemblies
d) Robust manufacturing capabilities
e) Robust product data management (PDM) capabilities

With these extras, CAD/CAM systems help automakers significantly shorten their design-to-market time. Although they are very powerful, but automobile development still require special purpose software in some specific area. For example, Figure 1.4 shows different software's in entire BMW development.

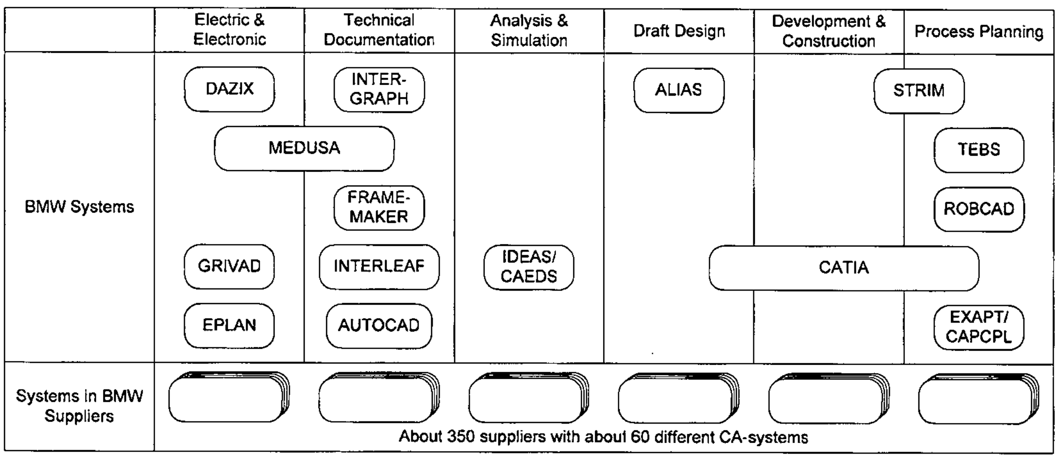

Figure 1.4: Use of Different Software in BMW Construction [7]

Figure 1.5 shows an example of an automobile that has been design in CATIA, a CAD/CAM software.

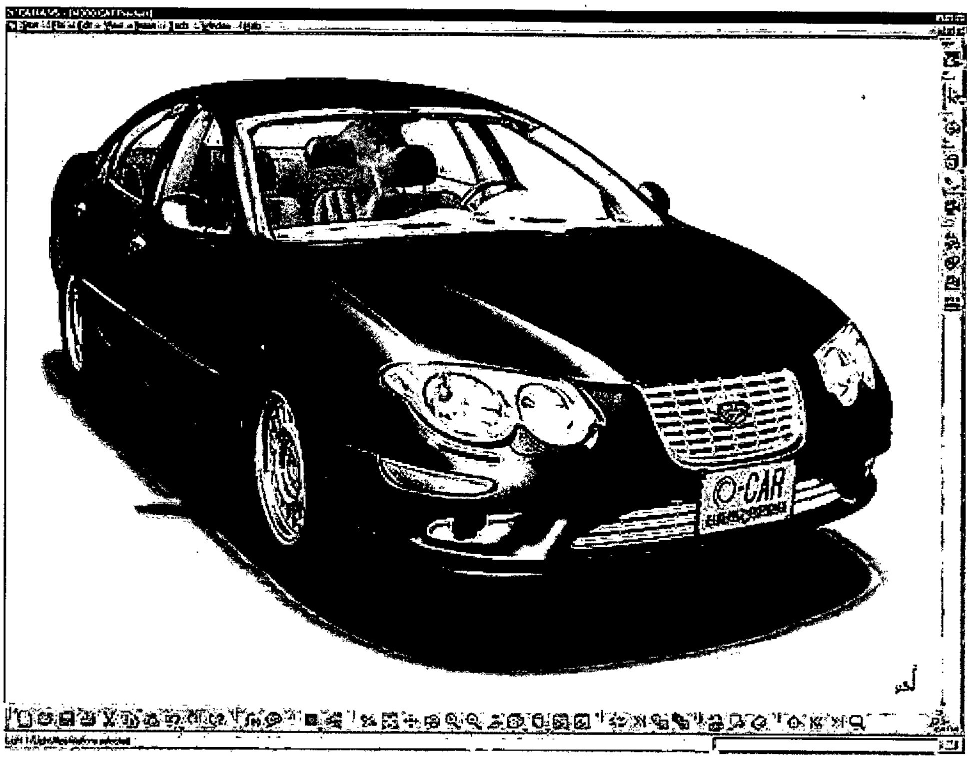

Figure 1.5: Real Time Rendering of a Car by CATIA [8]

1.1.3 CAD Data Transfer

Referred to the automotive supply chain and the role of CAD/CAM in automotive, it is easy to see the big picture of how frequent a model data of automotive part will exchange in order to complete a development of an automobile. In the case of Malaysia, automotive OEM; Proton and Perodua are using CATIA V4 as their main CAD software. The software is affordable for big vendors of these two automakers. But it is very costly for small vendors. Hence, supply chain for Proton and Perodua contained many type of software and hardware that require different file format of model data. Even though in the OEM companies itself, different department require different file format. This situation suits best for testing and analysis process. Engineer there require compatible file format for simulation on aerodynamic, crash and others. Therefore, CAD data transfer is happen inter-organization and also intra-organization. For inter-organization data exchange, Figure 1.6 shows three main methodologies on how it is being done.

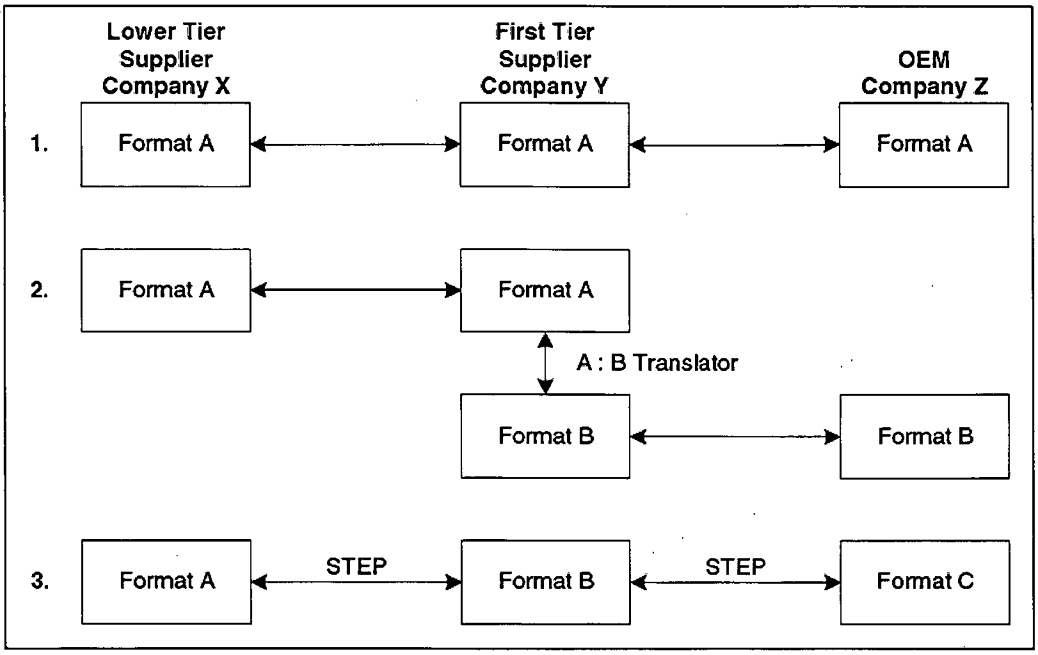

Figure 1.6: CAD Data Exchange Inter-organization [2]

Panel 1 in Figure 1.6 shows the use of single-system standards. Single-system standards are situations where every participant within a market speaks the same language. Every supplier and demander uses the same data format to transfer information from one user to another. This approach maximizes interoperability and minimizes financial outlays by each organization because only one software package is needed. However, it prevents customization of software or other technology to maximize its usefulness to each individual participant in the market. When users in a supply chain are exchanging product model data that has been created using the same software package it is said that they are accomplishing native format file transfers.

Panel 2 shows the use of custom translators. In this setting, each individual pair of suppliers and demanders purchases the technology that is best for their transactions. Translators directly convert files from one format to the other so that the users can access each other's data. Interoperability is significantly lacking from this approach. Although multiple organizations within the same industry may use the same software, there is no reason to expect that all will. In addition, each organization may customize their software based on their particular production function. If a supplier wants to interact with more than one customer, it must buy and install a completely different CAD/CAM/CAE package.

The third approach to transferring data, Panel 3, is the use of neutral format exchange. Each organization can pick the software that most efficiently manages and controls the intra-organization or intra-division flow of information. When the organization conducts an inter-organization or interdivision exchange, it first translates the data into a neutral format that is accessible to all software applications. This approach maximizes interoperability across and within organizations. However, the software development costs increase because a translating package is added to or incorporated into the software. Table 1.1 summarizes the tradeoffs between the three schemes in terms of interoperability, capital investment, and flexibility.

Table 1.1: Comparison of Data Exchange Methodologies [2]

	Interoperability	**Financial Outlays**	**Flexibility**
Single System	High	Low	Low
Custom Translators	High	High	Low
Neutral Format Exchange	Medium	Low	High

1.1.4 Type of Translation

There are two main categories of translation, dumb geometry translation and feature based translation.

1.1.4.1 Dumb Geometry Translation

When a CAD model is translate by using standards like IGES or STEP, the output is called dumb geometry. Dumb geometry or sometimes called dumb solid is a conversion of the geometry only, with no information about how it was created. Neutral files like IGES and STEP are dumb geometry. They create boundary curves along the edges, and boundary surfaces from all of the geometric features of the part and translate only these geometric features. This type of translation results in a solid model that is very difficult to modify. For example, if a user needs to change the location of a hole, he or she cannot redefine it with the CAD system and move it to a new location. He/she can't even erase the hole. Dumb solids are acceptable if what users need is a 3D picture of the part. However, he/she will not be able to use the part as the basis for a new design, or revise the design. Dumb solid files are inadequate for real collaboration efforts because they do not provide true interoperability between different CAD systems.

1.1.4.2 Feature Based Translation

Feature based translation is the most perfect translation method between different CAD systems that available today. Unfortunately this service requires a very high price and it is not a standard. A feature based or native file translation provides a direct database conversion of models with the feature history tree intact; all original geometry and geometric features created in the original model are recreated in the specified target software application. For example, if the source system is Unigraphics and the target system is Pro/ENGINEER, all of the geometry and geometric features contained in Unigraphics would be re-created in Pro/ENGINEER. Most of feature based translation services today support four high-end CAD/CAM systems; CATIA, Pro-Engineer, I-DEAS and Unigraphics. This is because the demand for this service most founded in these systems.

Feature recognition software introduces new intelligence to a static model or re-establishes the intelligence that went into the creation of a model. It gives engineers the ability to make changes easily, reuse unique features and test their design creativity, spending energy and effort on the design process instead of the translation process.

Parametric feature recognition software for CAD users recognizes features from files produced by standard data translation formats, reapplying intelligence to the static geometric data. Keeping model features intact between CAD programs preserves design intent and maintains quality.

An example of such a feature would be a hole. With this parametric feature recognition software, whether the hole was created as a simple, tapered, counter-bored, blind or through-all feature, its essential specification, which may have been lost through the data translation process, is retained. This approach to CAD interoperability leverages past work and provides a tool for reusing rather than redesigning parts.

Figure 1.7 shows an example of a model that has been translated using feature-based translator. First figure shows a design in that has been translated into CATIA V4 format. Second one shows the same design in Unigraphics. The real model was design in CATIA V5.

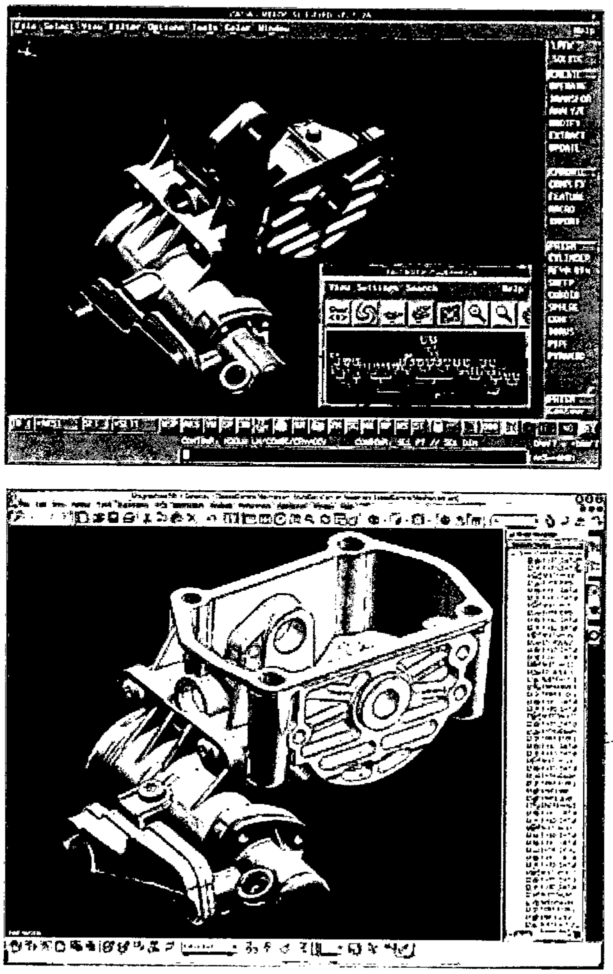

Figure 1.7: Sample of feature based translation job

Other common features that can be translated are listed below;-

1. Sketches with dimensions and geometric constraints
2. Datums and reference geometry
3. Protrude/Extrude features
4. Revolve features
5. Simple lofts
6. Round, fillet and chamfer
7. Shell
8. Draft
9. Patterns
10. Colour
11. Assembly constraints

Standard translation did not included feature in translation which will result a dumb geometry file. The file cannot be modified in the way it was designed. This problem can be overcome by remaster the dumb geometry into full featured file, but that will take very long time.

Another function that feature based translation have is it can translate the model with all the history. History is the data of model development from the start; step by step. The history is essential for post-editing, where users can track back how the model is being drawn. In standard translation, this data did not translated, resulted an extra time required for editing process.

1.1.5 Data Losses

Neutral format data exchange standards such as IGES and STEP are extensive in structure and scope. This is in an attempt to support a varied field of disciplines; CAD and CAM are only two among many. In the process of neutral format data exchange, a 3D model file is translated from one native CAD format (sending system) to an IGES or STEP file. This file is then translated into another native CAD format (receiving system).

The process involves extensive entity mapping. The sending system maps native entities to supported neutral entities. The receiving system then has to map the neutral entities in the IGES or STEP file into its own native CAD entities. Sometimes this entity mapping can change the definition of the native CAD entity, such as mapping an analytical arc or cylinder to a B-spline curve surface. During the process, the original definition of an entity can get lost. This loss of definition in most cases has become acceptable.

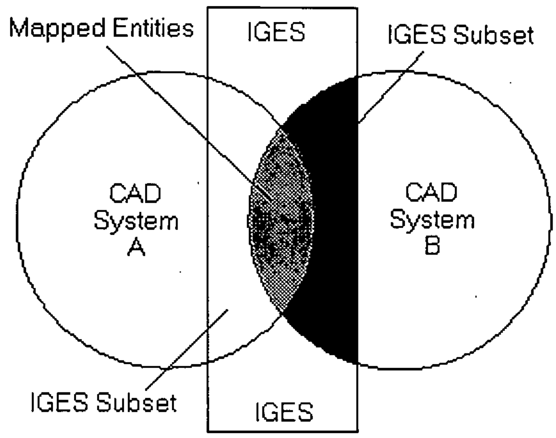

Figure 1.8: Each CAD System Supports a Subset of the IGES Standard [9]

Also, because of the size and scope of the standard, CAD/CAM systems will only support a subset of the standard, which is illustrated in Figure 1.8. The entity types supported by both systems are mapped from the sending system to the receiving system. Other entities with the subset may be ignored. While System A may support entities a, b, c, d and e, System B only supports entities a, c and e. Entities b and d are ignored by System B because it chooses not to support those entities. This is another way in which data can be lost.

Data can also be lost due to non-support during every translation. This can occur when the two systems are fundamentally incompatible (such as between a high-end and a low-end system) or when the receiving system is outdated.

3D data loss can also occur due to human programming errors - how well the CAD/CAM systems write out (translate to IGES or STEP) and read in data (translate from IGES and STEP). It depends on how true the programmers that write the translators are to the specifications documented in standards. The specifications are open to interpretation and programmers then have to program their translators to act accordingly. Programmers are also human and are prone to human error.

1.1.6 Translation Cost

The cost of translation is varied, depending to the service provider. List below are the pricing for translation that delivered by Mathdata. All the price stated below are in US Dollar ($). At the time this research being done, the conversion rate is one US Dollar equal to 3.8 Malaysia Ringgit (RM).

1.1.6.1 Standard Neutral Translations

For neutral translations there is a per-file charge of $20 for the first MB then $5 per MB for every subsequent MB. Does not include repairs or healing services which, if required, will be quoted in advance. Minimum charge is $65 per file. Includes all neutral formats; IGES, STEP, Parasolids, STL, VDA, & ACIS.

There is an additional 50% surcharge for next step translation, where the source file is translated into target system by neutral format as intermediate process. Systems supported are: CATIA, Unigraphics, SDRC I-DEAS, Pro Engineer, AutoCAD, MasterCAM, SolidWorks and SolidEdge.

For large file or assembly, there is extra charge for the services to separate the file into its individual components or into any other logical units and export those as individual files. This facilitates give ability to manipulate the data even with entry level workstations. This service requires an additional 25% of the standard fee.

All pricing and delivery is determined by analyzing the files and preparing a specific quotation of price and expected lead-time. Overall minimum charge is $65.

1.1.6.2 Feature Based Translations

For typical part files, the charge is $140 in single quantities. The word "typical" defined as a part that have one with up to approximately 100 features that are prismatic in nature (i.e. mostly comprised of extruded or revolved features).

Parts that fall outside of the definition of "typical" are quoted based on the number and complexity of the features that comprise the part. For example, parts that consist of complex surface features, or parts that contain large numbers of features (such as a casting with complex blends and draft angles) are more expensive to translate than typical parts.

Assemblies are quoted based on the number of parts in the assembly and the average complexity of the parts as defined above. All pricing and delivery is determined by analyzing the files and preparing a specific quotation of price and expected lead-time.

Example of the part model that fall into the three categories is given in Figure 1.9, Figure 1.10 and Figure 1.11 respectively.

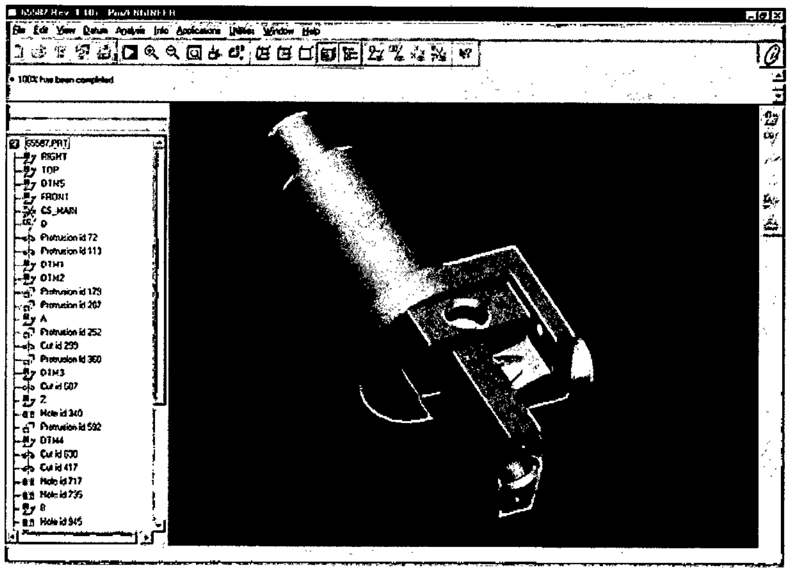

Figure 1.9: Example of a Typical Part. Cost: $140