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Interoperability Analysis of CAD Applications

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Abstract—Computer-Aided Design is used on a day to day basis by millions of people across the world. Various different CAD File types and CAD Applications are used for this. This gives rise to a competition between the various CAD File types as well as the applications. Most of this data is undocumented in the public domain, and exists only in the private research data by big firms.The data that is documented is now redundant as there have been various advances in the field of CAD Softwares. Thus, all firms or individuals need to do their own research into the advantages and disadvantages of various applications and file types for their work.

This paper aims at providing a detailed comparison of various neutral as well as native CAD File types and applications that are commonly used by CAD Vendors. It will cover their advantages and disadvantages, as well as statistical data based on perceived errors in various mass properties.

Keywords—Computer Aided Design,Filetype, Softwares, Interoperability

I. INTRODUCTION

Computer-Aided Design is the usage of computer system for designing various CAD is used on a day to day basis by millions of people across the world. Different CAD File types have been developed for this by various different organizations, each having its own advantages and disadvantages. Various organizations have also developed their own CAD applications for this. This has given rise to a competition between the various CAD File types as well as the applications. There is very little research on different CAD File types that is up to date and is publically available. Most of the research is privately conducted by various firms for their own usage. The data that is documented is now redundant as there have been various advances in the field of CAD. Thus, all firms or individuals need to conduct their own research on the various applications and file types for their work from time to time.

CAD Filetypes can be differentiated into two main categories – Native and Neutral. Native File types are those that are designed specifically by a CAD Implementer for their own CAD Software. These are not easily readable, and are usually encoded. Mostly only the application they are built for are able to export models using them, while other applications need to buy licensing information for importing them using their own applications.

Neutral FileTypes are those which can be used by any application to export as well as import depending on compatibility. These can be easily used to transport data between applications, and serve as efficient mediums.

Section II gives a brief introduction to related works on the topic and their shortcomings. It also serves as an introduction as to why this paper is required.Section III gives an introduction to the various CAD File types and CAD Applications that will be used for this paper.Section IV presents the results of the study in a systematic manner so as to make it easier for readers to understand. Section V provides the conclusion obtained from this study as well as future scope.

Abbreviations and Acronyms used in this paper:

CAD – Computer Aided Design
JT – Jupiter Tessellation[1]
STEP – Standard for Exchange of Product Model Data
U3D – Universal 3D
Cr – PTC Creo 3.0
Inv – Autodesk Inventor 2015
SW – Dassault Systemes SolidWorks 2015
SE – Siemens Solid Edge ST8
NX – UGS NX 10

Units used: Inch-lbmass-second
[All data is in above units. In case data was not obtained in these units, it has been converted into corresponding units as above.]

II. RELATED WORKS

There is a small amount of data publically available for readers, while most of the investigation and research is carried out individually by private firms for their own goals. The latest documentation from 2012 by Dillon McKenzie-Veal[2] is an extensive and well-formed study of the various CAD File types. Yet, the shortcoming with it is that CAD softwares have since evolved, and thus there is a need for their reanalysis. Various shortcomings found in CAD Softwares for that study have since been addressed, and as softwares have evolved, new errors and compatibility problems have also arisen along with better User Interfaces and functionality. The CAD Filetypes addressed in it are JT (Jupiter Tessellation), STEP (Standard for Exchange of Product Model Data), 3D-PDF, and native file types of Pro/E, Autodesk Inventor, UGS NX, CATIA and SolidWorks.

The second study by Nathan Hartman[3] is yet older than the first one, and addresses only a few CAD File Types, including 3D-XML, JT, U3D (3D-PDF), STEP. The study is from 2008 and is suited to CAD standards then, but quite limited in its functionality compared to standards today.

The next three studies by Aerospace and Defence Assoc. of Europe[4], ProSTEP Alain Pfouga[5]and Josip Stjepandić[6]from 2015 stresses on 3D CAD Data in Product Life Cycle, and covers only certain features of various CAD Filetypes, but again have limitations with the goal to compare CAD File Types.

Thus, it is imperative that such studies be conducted from time to time to keep up the dynamically changing CAD Systems. This papers aims at providing the data of such a study.

III. CAD File Types

Multiple file types are taken into consideration for this study. They can be loosely categorized into two types, Native and Neutral CAD File types.

3.1 Native CAD File Types:

Native CAD File Types are those that are built specifically for the software by the company that owns it. APIs can be developed by the company for other softwares to export/import the file types. The Native File Types taken into consideration for this research are as follows:

PTC Creo:	PRT & ASM files
Autodesk Inventor:	IPT & IAM files
Dassault SolidWorks:	SLDPRT & SLDASM files
Siemens Solid Edge:	PAR file
Siemens NX:	PRT files

3.2 Neutral CAD File Types:

Neutral File Types are the filetypes that are exportable and importable for free or with some subscription fee by CAD applications. These are often used as intermediate files for data transfer.The Neutral File Types taken into consideration for this research are as follows:

JT
STEP
U3D (3D-PDF)

Of these, STEP is also readable as a text file while JT and U3D can be read only by CAD softwares or directly through licensed APIs.

IV. Algorithm

The results of the research were obtained by building benchmark models. These models were built in all the CAD Softwares used for this study with as much similarity as possible. The parameters used for this study include Volume, Mass, Density, Surface Area, Compatibility, Centre of Mass.

The benchmark models developed using one software will be exported to other possible file types. This will give the results of exportability.

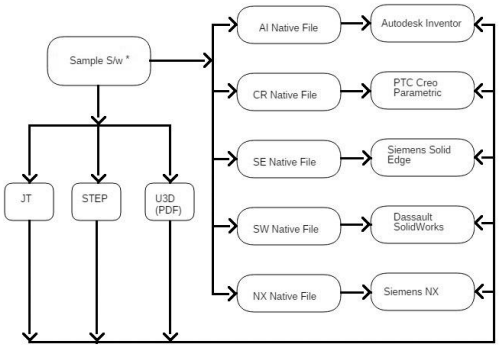

Figure 1 Exporting File Types

The exported and original files will then be imported using the original as well as other softwares to obtain results of compatibility.

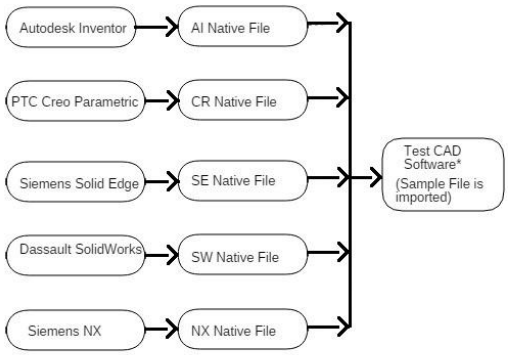

Figure 2 Importing File Types

Statistical Data will be formed on how well the given software is able to export to and import from other CAD file types.

Error was calculated using the formula

$$\%\ \text{Error} = \left| \frac{\text{Theoretical Value} - \text{Experimental Value}}{\text{Theoretical Value}} \right| \times 100$$

The following Benchmark Models were created using the various CAD Applications. The material chosen was Cast Iron with density 0.2583 lb/in^3.

Figure 3CAD Models (L to R)
Inventor, Solid Edge, SolidWorks, Creo, NX

V. RESULTS

The following results were obtained from the the research:

5.1 Compatibility:

Benchmark files were created using specified softwares and imported using the other softwares. The following table shows the import and export capabilities:

From S/w / To Format	Cr	Inv	SE	SW	NX
Cr prt & asm	I/E	I	I	I/E	-
Inv ipt and iam	I	I/E	I	I	-
Se par	I	-	I/E	I	I
Sw sldprt/sldasm	I/E	I	I	I/E	I
NX prt	I/E	I	I	I	I/E
JT	I/E	I/E	I/E	-	I/E
STEP	I/E	I/E	I/E	I/E	I/E
U3D	E	-	E	-	-

I - Import possible
E - Export possible

5.2 Mass Properties:

The benchmark models were created using the different CAD softwares with as much similarity as possible. However, to avoid errors being introduced due to model dissimilarity, two models generated from different softwares will not be compared against each other. Here, only the corresponding part files are taken into consideration

5.2.1 PTC Creo

Creo PRT File

Creo	**Volume**		**Mass**		**Area**		**Centre of Gravity**
	Value	Error	Value	Error	Value	Error	Value
Original	1.9076665	N/A	0.49276961	N/A	21.151066	N/A	-0.00006, -0.12240, 0.60017
Inv*	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Se	1.907361377	0.015995	N/A	N/A	21.1611352	-0.04761	-0.00009, -0.12229, 0.60002
Sw*	N/A	N/A	N/A	N/A	N/A	N/A	N/A
NX**	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Creo	1.9076665	0	0.49276961	0	21.151066	0	-0.00006, -0.12240, 0.60017

* - Version Incompatible
** - File Type Incompatible

Creo JT File

Creo	**Volume**		**Mass**		**Area**		**Centre of Gravity**
	Value	Error	Value	Error	Value	Error	Value
Original	1.9076665	N/A	0.49276961	N/A	21.151066	N/A	-0.00006, -0.12240, 0.60017
Inv	1.907	0.034938	0.49259744	0.034938	21.158	-0.03278	-0.000, -0.122, 0.600
Se	1.863092866	2.336553	N/A	N/A	20.6769197	2.241713	-0.00011, -0.12585, 0.60863
Sw**	N/A	N/A	N/A	N/A	N/A	N/A	N/A
NX	1.90818276	-0.02706	0.49290296	-0.02706	21.15156	-0.00234	-0.00008, -0.12254, 0.60049
Creo	1.907734	-0.00354	0.49278704	-0.00354	21.15354	-0.0117	-0.00007, -0.12240, 0.60018

Creo STEP File

Creo	**Volume**		**Mass**		**Area**		**Centre of Gravity**
	Value	Error	Value	Error	Value	Error	Value
Original	1.9076665	N/A	0.49276961	N/A	21.151066	N/A	-0.00006, -0.12240, 0.60017
Inv	1.914	-0.332	0.494	-0.24969	21.161	-0.04697	-0.000, -0.129, 0.605
Se	1.907506317	0.008397	N/A	N/A	21.1578596	-0.03212	-0.00008, -0.12230, 0.60018
Sw	1.91	-0.12232	0.5	-1.4673	21.15	0.00504	0.00, -0.12, 0.60
NX	1.90751	0.008204	0.49272918	0.008203	21.1581	-0.03326	-0.00007, -0.12235, 0.60010
Creo	1.9076665	0	0.49276961	0	21.151066	0	-0.00006, -0.12240, 0.60017

5.2.2 Autodesk Inventor
Inventor IPT File

Inventor	**Volume**		**Mass**		**Area**		**Centre of Gravity**
	Value	Error	Value	Error	Value	Error	Value
Original	1.951	N/A	0.504	N/A	19.848	N/A	0.000, -0.129, 0.615
Inv	1.951	0	0.504	0	19.848	0	0.000, -0.129, 0.615
Se	1.95145396	-0.02327	0.50408034	-0.01594	19.8481560	-0.00079	-0.00000, -0.12874, 0.61505
Sw	1.95	0.051256	0.5	0.793651	19.85	-0.01008	0.00, -0.13, 0.62
NX**	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Creo	1.951454	-0.02327	0.50408034	-0.01594	19.848156	-0.00079	0.00000, -0.12874, 0.61505

Inventor JT File

Inventor	**Volume**		**Mass**		**Area**		**Centre of Gravity**
	Value	Error	Value	Error	Value	Error	Value
Original	1.951	N/A	0.504	N/A	19.848	N/A	0.000, -0.129, 0.615
Inv	1.951	0	0.504	0	19.848	0	0.000, -0.129, 0.615
Se	1.95145396	-0.02327	0.50408034	-0.01594	19.8481560	-0.00079	-0.00000, -0.12874, 0.61505
Sw**	N/A	N/A	N/A	N/A	N/A	N/A	N/A
NX	1.95145396	-0.02327	0.50408035	-0.01594	19.8481560	-0.00079	0.00077, -0.08768, 0.52599
Creo	1.9514525	-0.02319	0.50406018	-0.01194	19.848148	-0.00075	0.00077, -0.08765, 0.52591

Inventor STEP File

Inventor	**Volume**		**Mass**		**Area**		**Centre of Gravity**
	Value	Error	Value	Error	Value	Error	Value
Original	1.951	N/A	0.504	N/A	19.848	N/A	0.000, -0.129, 0.615
Inv	1.951	0	0.504	0	19.848	0	0.000, -0.129, 0.615
Se	1.95145396	-0.02327	0.50408034	-0.01594	19.8481560	-0.00079	-0.00000, -0.12874, 0.61505
Sw	1.95	0.051256	0.51	-1.19048	19.85	-0.01008	0.00, -0.13, 0.62
NX[1]	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Creo	1.951454	-0.02327	0.50408034	-0.01594	19.848156	-0.00079	0.00000, -0.12874, 0.61505

[1]Unable to extract mass properties

5.2.3 Siemens Solid Edge

Solid Edge Par File

Solid Edge	**Volume**		**Mass**		**Area**		**Centre of Gravity**
	Value	Error	Value	Error	Value	Error	Value
Original	1.805294	N/A	0.4663257	N/A	22.156076	N/A	0.00000, 0.647331, -0.632096
Inv**	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Se	1.805294	0	0.4663257	0	22.156076	0	0.00000, 0.647331, -0.632096
Sw	1.89	-4.69209	0.48820617	-4.69210	21.7	2.058469	0.00, 0.59, -0.61
NX	1.8881705	-4.59075	0.48773359	-4.59075	21.701075	2.053617	-0.00001, 0.58279, -0.60728
Creo	1.8668645	-3.41055	0.47885779	-2.68741	22.394524	-1.07621	0.0000, 0.58260, -0.60717

Solid Edge JT File

Solid Edge	**Volume**		**Mass**		**Area**		**Centre of Gravity**
	Value	Error	Value	Error	Value	Error	Value
Original	1.805294	N/A	0.4663257	N/A	22.156076	N/A	0.00000, 0.647331, -0.632096
Inv	1.805	0.016285	0.46624981	0.016273	22.156	0.000343	-0.000, 0.548, -0.589
Se	1.805294	0	0.4663258	-0.00002	N/A	N/A	0.000000 0.016442 -0.016055
Sw**	N/A	N/A	N/A	N/A	N/A	N/A	N/A
NX	1.805294	0	0.4663257	0	22.156075	0	-0.0000, 0.548489, -0.588749
Creo	1.8052934	0.00003	0.4663255	0.00004	22.15607	0.00002	0.00000, 0.64307, 1.0757

Solid Edge STEP File

Solid Edge	**Volume**		**Mass**		**Area**		**Centre of Gravity**
	Value	Error	Value	Error	Value	Error	Value
Original	1.805294	N/A	0.4663257	N/A	22.156076	N/A	0.00000, 0.647331, -0.632096
Inv	1.805294347	-1.9E-05	0.46632584	-0.00003	22.1560760	0	0.00165, 0.59653, -0.6049
Se	1.805294	0	0.4663258	-0.00002	N/A	N/A	-0.00000, 0.54849, -0.58875
Sw	1.81	-0.26068	0.46754136	-0.26068	22.16	-0.01771	0.00, 0.21, -0.39
NX	1.80648169	-0.06579	0.46663254	-0.06580	22.1560756	1.52E-06	-0.000005, 0.61951, -0.63483
Creo	1.8052944	-2.2E-05	0.4663258	-0.00002	22.156076	0	0.0000, 0.20735, -0.39431

5.2.4 DassaultSolidWorks

SolidWorks SLDPRT

SolidWorks	**Volume**		**Mass**		**Area**		**Centre of Gravity**
	Value	Error	Value	Error	Value	Error	Value
Original	1.76	N/A	0.46	N/A	21.64	N/A	0.50, -0.08, 0.00

Inv*	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Se	1.788171	-1.60063	0.46190271	-0.41363	21.701075	-0.28223	0.49842, -0.084645, 0.00
Sw	1.76	0	0.46	0	21.64	0	0.50, -0.08, 0.00
NX*	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Creo	1.7627434	-0.15587	0.45533449	1.014241	21.638733	0.005855	0.49849, -0.84732, -0.000019

SolidWorks STEP

SolidWorks	**Volume**		**Mass**		**Area**		**Centre of Gravity**
	Value	Error	Value	Error	Value	Error	Value
Original	1.76	N/A	0.46	N/A	21.64	N/A	0.50, -0.08, 0.00
Inv	1.763	-0.17045	0.455	1.086957	21.641	-0.00462	0.499, -0.085, 0.000
Se	1.762645767	-0.15033	0.45530928	1.019721	21.638548	0.00671	0.49842, -0.084645, 0.00
Sw	1.76	0	0.46	0	21.64	0	0.50, -0.08, 0.00
NX	1.7626	-0.14773	0.45864	0.295652	21.63827	0.007994	0.49842, -0.08478, 0.00001
Creo	1.7627345	-0.15537	0.45533	1.015217	21.638689	0.006058	0.49849, -0.84730, -0.00001

As SolidWorks cannot export to JT File Type, its results are not considered here.

5.2.5Siemens NX

NX PRT

NX	**Volume**		**Mass**		**Area**		**Centre of Gravity**
	Value	Error	Value	Error	Value	Error	Value
Original	1.685026532	N/A	0.43525945	N/A	21.0460757	N/A	0.46876, 0.07361, -0.04374
Inv*	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Se	1.68489	0.008102	0.435224	0.008144	N/A	N/A	0.46889, 0.07362, -0.04370
Sw*	N/A	N/A	N/A	N/A	N/A	N/A	N/A
NX	1.685026532	0	0.43525945	0	21.0460757	0	0.46876, 0.07361, -0.04374
Creo	1.6850502	-0.00140	0.43526556	-0.00140	21.046174	-0.00046	0.46878, 0.07361, -0.04375

NX JT

NX	**Volume**		**Mass**		**Area**		**Centre of Gravity**
	Value	Error	Value	Error	Value	Error	Value
Original	1.685026532	N/A	0.43525945	N/A	21.0460757	N/A	0.46876, 0.07361, -0.04374
Inv	1.68477471	0.01494	0.4351944	0.014944	21.0415602	0.021455	0.46862, 0.07362, -0.04370
Se	1.685026555	0.00	0.43525945	0.00	N/A	N/A	0.46889, 0.07362, -0.04370
Sw**	N/A	N/A	N/A	N/A	N/A	N/A	N/A
NX	1.685026532	0	0.43525945	0	21.0460757	0	0.46876, 0.07361, -0.04374
Creo	1.6822445	0.165103	0.43454082	0.165103	21.013551	0.154540	0.47184, 0.07406, -0.04455

NX STEP

NX	**Volume**		**Mass**		**Area**		**Centre of Gravity**
	Value	Error	Value	Error	Value	Error	Value
Original	1.685026532	N/A	0.43525945	N/A	21.0460757	N/A	0.46876, 0.07361, -0.04374
Inv	1.685621415	-0.03530	0.43541311	-0.03530	21.0511997	-0.02434	0.46909, 0.07362, -0.04389
Se	1.686635	-0.09545	0.4356749	-0.09544	N/A	N/A	0.46889, 0.07362, -0.04370
Sw	1.67325	0.698892	0.43221745	0.698892	21.053	-0.03290	0, 0, 0.54
NX	1.685045315	-0.00111	0.4352643	-0.00111	21.0461298	-0.00025	0.46878, 0.07361, -0.04375
Creo	1.6850671	-0.00240	0.43526993	-0.00240	21.046287	-0.00100	0.46879. 0.07361, -0.04375

VI. Conclusion

From above data, it can be observed that all softwares are perfectly compatible with their own native filetypes. However, some minor data might be lost while translating into the native filetypes of other applications as well as neutral filetypes due to accuracy and approximation.Different applications have their own advantages and disadvantages depending on what parameters they stress on.

Acknowledgment

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