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Research Result Differences Between Manual Research and Using AI LLMs for Analyzing Popular 3D File Formats

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***Abstract* – A literature review has been conducted, helping outline some of the main peculiarities that exists within the 3D object file format domain. The difficulties that are present when working with different file formats in various fields have been noted – incompatibility issues, data loss, conversion difficulties, software wrappers, manufacturing industry standards and more. The problem of file format comparison has been defined – workflows are bogged down by the different output software tools use, expertise in different fields is a requirement, difficulties with conversion, complexity of file formats themselves and proprietary solutions, all lead to tremendous amount of manual work and technical knowledge required to keep track of differences between 3D file formats. As web sources for file format information can often become unreliable with time, new sources become available and analysis are constantly made, an argument has been made to try and use LLMs to alleviate some or most of the workload in file comparison. Such research necessitates a researcher to manually check all the output data of a model, in order to verify the correctness and accuracy of the used model. A methodology for the research process has been developed and implemented.**

Its main points include the definition of criteria for comparison, using manufacturing industry expert opinion to further verify the validity of the researcher and LLMs statements and the criteria itself, creation of comparison tables based on the criteria for all the chosen formats, short descriptions of the file formats themselves by the researcher and by the LLM and their comparison, as well as an analysis of file formats searchability on google trends. A comparison of binary data for some file formats is shown and described for further understanding of the issues with metadata and understanding proprietary 3D file formats. ISO standards for STEP ISO 10303-242:2022 and IGES, as well as their effects on the industry are briefly discussed. File formats that are discussed and compared: OBJ (Waveform obj, .obj); FBX (Filmbox, .fbx); glTF (GL Transmission Format, .glTF, .glb); USD/USDZ (Universal Scene Descriptor, .usd, .usdz); BLEND (Blender file format, .blend); AMF (Additive Manufacturing, .amf); STL (Stereolithography, .stl); 3DS (3D Studio Scene, .3ds); IGES (Initial Graphics Exchange Specification, .igs, .iges); STEP (Standard for the Exchange for Product Data, .stp, .step); DAE, Collada (Digital Asset Exchange File, .dae).

***Keywords* – 3D file formats, AI LLM research, binary file comparison, google trends observation.**

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1. Introduction

The main types of 3D object visualization are usually grouped by their use – in manufacturing and engineering, in movies and games, in architecture, in medicine, as well as those used to transfer data between each other. The different file formats that have emerged to serve the software that helps with servicing the needs of each of those groups store data in different ways. Standards were created to help unify the requirements, the most popular of those still see extensive use today – STL, AMF [15], STEP [16], IGES [17], X3D [18]. The newest currently recognized public standard for creating 3D file types on the web is GLTF [19] - created by Kronos Group. The format stores data in JSON (like OBJ) and strives to capture as much data as possible.

The open-source documentation is detailed and comprehensive, hosted publicly for free.

2. Literature Review

The abundance of 3D file formats, their lack of well adopted standardization, and high level of proprietary technology used in most of them, complicates the research process. The loss of data due to conversion between formats is a problem [1], and it remains a time sink for engineers and artists who must work on projects using different types of software. With the gradual maturing of 3D printing technologies, the file formats have grown to accommodate exporting to STL or relevant formats, but experts are still facing fundamentally different approaches to saving 3D objects.

Several peculiarities that must be mentioned are:

1. Some relations/constraints/links between the components disappear when transitioning file types. The objects themselves maintain their correct position in the scene, but the connection to the other parts or objects is severed. As an example, if there is a bolt that should rotate out of its nut, when their relational links are lost, the bolt will simply come out in a single straight motion, instead of rotating and sliding out according to the direction of its pitch.

2. 3D file formats are used for different purposes – thus they require categorization. Some are used for design and architecture, and they require great lighting and texture pattern details. However, in 3D printing this is often not a requirement at all, nor is it in engineering. Different purposes for using 3D file formats include but are not limited to – graphic design, VFX, film making, video game making, CAD for engineering, CAD for architecture, 3D printing, 3D scanning and viewing, holographic simulations, AR applications, Additive manufacturing, etc.

3. Choosing which type of file format to use is highly dependent on the workflow in an organization. This usually leads to difficulties when introducing a new technological stack, or even when updating tools to their newer versions. This is especially true in the manufacturing industry, where manufactured items must be available for recreation for long periods of time, so older versions of software must be supported. This problem is less prominent in the artistic industry, where backwards compatibility is not critical to success.

4. Many proprietary formats exist. There are benefits to this – guaranteed measure of quality, linked to company responsibility, dedicated software for 3D manipulation that is optimized for native proprietary formats, reasonable user support by companies. Some of the drawbacks include – a hefty subscription fee to use the software, less learning materials (compared to open-source community driven software), incompatibility between different software tools, black box file formats that are difficult to modify or optimize externally, difficulties with file format version control.

5. Preference for custom solutions – teams and experts are creating their own formats and software that builds on existing formats to fit their specialized purposes – such as visualizing 3D objects using the OBJ file format [2], [3]. If there was a do-it-all format like GLTF that could be more well adopted and popularized, an enormous amount of work on customized formats would be alleviated. If a format could be derived from and branched publicly, repurposed in a repository that was accessible and popular, there would not be such a flood of different file formats and file conversion data loss nightmares.

Even current research on 3D model creation based on audio recognition algorithms is limited by older file formats like STL [4], [5]. This is common in manufacturing - standards such as the ISO for STEP [16] are well-adopted in the industry. In the medical field 3D scanning and 3D printing have already been well received and are used in various ways.

The long and rigorous process of review and testing before publishing an ISO standard ensures that standards cannot keep up with the current break-neck speed of development. Safety is a primary concern when designing such standards, as it should be, but that leads to the already mentioned problems that constrain projects and research on new methods and technologies – leading to the development of custom solutions. Efforts have been made to apply the STEP file format by using G-Code [6] and shorten development cycles in machining.

An interesting example that showcases 3D Echocardiography the result of which is used to 3D print results for medical staff to analyze uses several layers of file conversion and manipulation (3D-TEE -> Qlab Station -> DICOM -> Slicer -> STL) to get to an STL file to print [7] (although modern DICON software supports direct export in STL, Slicer is used to further refine the product). Requiring multiple different tools and manipulation adds to the complexity and requirements of any such project. Dentistry also makes use of 3D scanning and printing technologies. Workflows in the field require working with files of 3D scans, and that often necessitates compression and sending them over the internet – be it for communication between doctors, or between buildings - if the 3D scanner is not directly connected to the computers the dentists will use. Research has been conducted to assure that there is a lack of deformities and anomalies that occur during the compression and sending process of such files [8].

Attempts have been made at combining different file formats in the same scene to streamline workflow burdens through increasing interoperability between file formats like Collada and X3D [9]. These efforts further prove the complexity of the tasks in front of everyone, as well as the need for a unified format or environment. Nvidia is currently fostering its product called "Omniverse", which is supposed to help with integrating different workflows with robotics, simulations, AI, 3D CAD tools, engineering and more. Research has been conducted to analyze whether the products' design guidelines are comprehensible by students, and it was proven that the product is possible to use with guidelines that are helpful [10].

3. Overview of the Problem

3D file formats are the lifeblood of workflows where CAD software is the heart. With the maturation of the 3D printing technology the STL standard has been recognized as the most robust result of workflows that lead to detail creation [11]. The age of the standard has its own detriments. It lacks details for the 3D objects that newer 3D printers can handle. Thus, there are formats like AMF that are its successors. This pattern is prevalent in the industry – technology changes so fast, capabilities rise so quickly, that there is no time for standardization to catch up. The ISO standardization process takes many years to complete, and by the time it is well defined and agreed upon, there are newer features being added to pipelines in the industry, as the demand for their implementation increases.

Standards are an absolute necessity - especially considering the nature of manufacturing and CAD instruments. They are designed with safety and easy long-term support in mind, by people with an incredible amount of experience in different fields. The most recognized such standards are STEP [12], [16] and IGES [13], [14]. Other fields, like architecture, arts, movie, and game creation have deviated from the ISO standards, instead relying mostly on proprietary solutions and individual company standards.

There have been attempts at introducing open-source formats that encompass all the necessary features of CAD instruments, and the current iteration of one such standard is glTF. It is very well defined, wholly open-source, and has great and thorough documentation. The problem lies in the adoption of the format – as of right now, not many software instruments, especially CAD, have included export options to the standard.

Herein lies the problem – a universal standard for 3D files is currently impossible to achieve. This complicates workflows, introduces reliability on proprietary formats, makes transitioning to different software instruments difficult and wastes a large amount of time when importing and exporting 3D objects for different purposes. The complexity of the conversion process is immense when considering how many different types of formats have been defined throughout the years, and how many of them must be supported in the future for backward compatibility.

A proposed alleviation of such complexity is: using large language models to crawl and compare existing data on the Internet to summarize results and create comparison tables that note the differences between 3D file formats. To evaluate the veracity of the LLM's statements, a human researcher must make the same analysis. By comparing the data, results can be evaluated, and conclusions can be made whether this solution is viable or not right now. It can be assumed that in the very near future this process will be automated (e.g. looping GPT researcher results). Another interesting approach would be to simply feed an LLM with several libraries with files of the same objects, saved using the different file formats for comparison, and offload the task of comparing the objects' binary representations. Currently open-source LLMs are not sophisticated enough to analyze such data, but this may well be how comparison research is done in the future. For the current experiment several file formats' binary code will be examined and differences will be showcased. This aims to bring differences to light – it is multidisciplinary knowledge on how to encode metadata and object details, so it has been deemed appropriate to demonstrate how important bits of the created files look like to the computer in binary.

It must be considered that the most thorough and publicly available cited research that could be found, which analyses 3D file formats has been created 16 years ago (as of this moment) [1]. That large time gap is understandable – the process of analyzing and comparing constantly changing file formats requires a large time investment and considerable industry knowledge. Leveraging automation (in the face of LLMs) would be beneficial for future workflow design.

4. Layout

Google trends is used for measuring the popularity of several file formats, data is taken from the year 2004 until the beginning of 2024.

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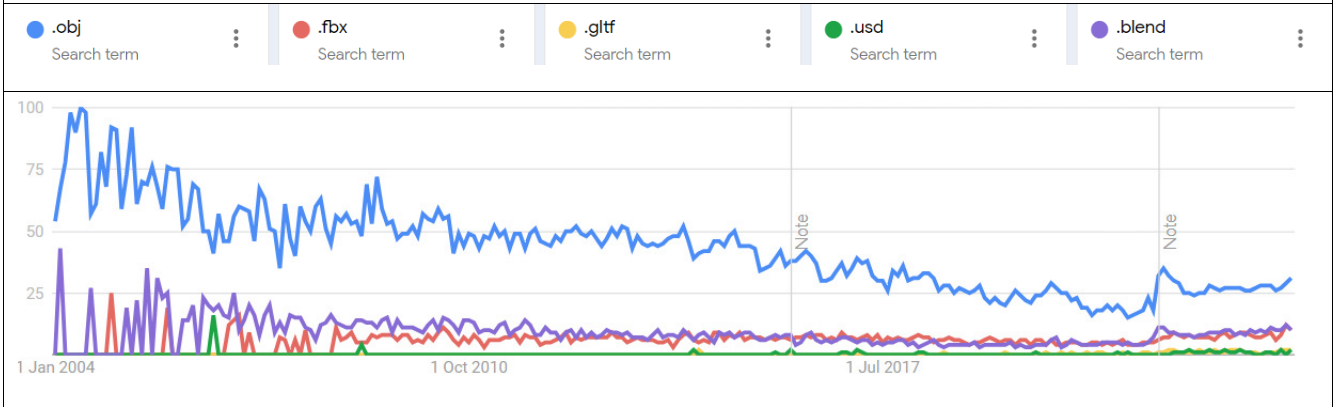
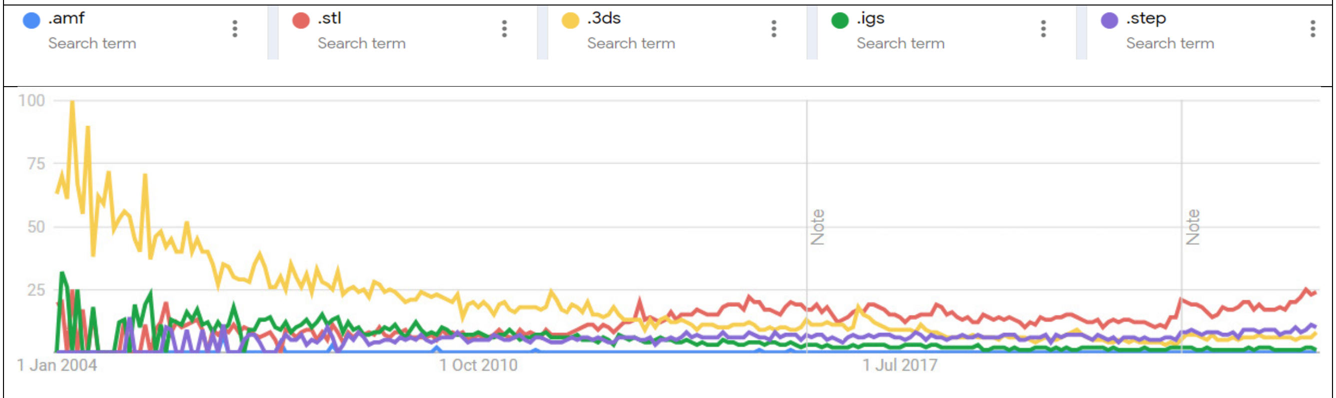
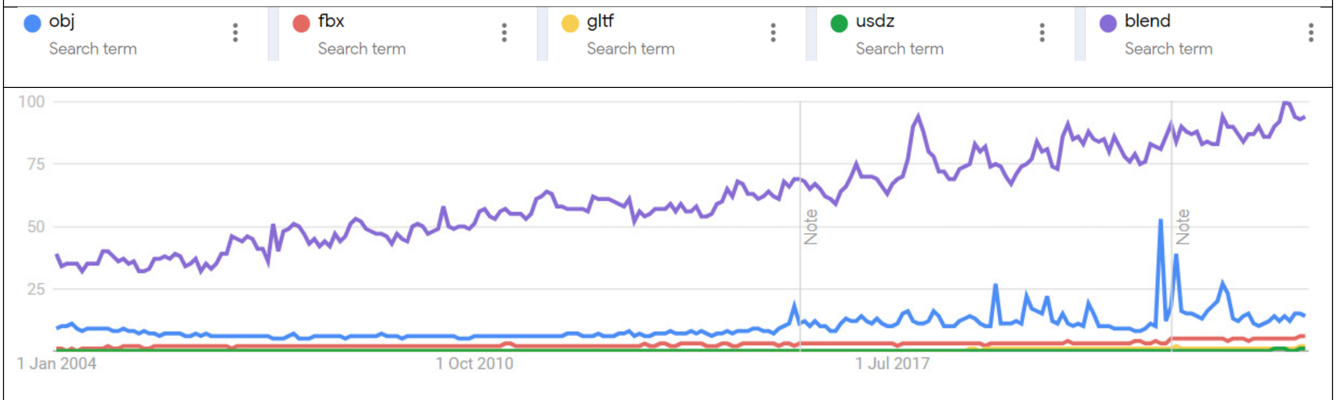
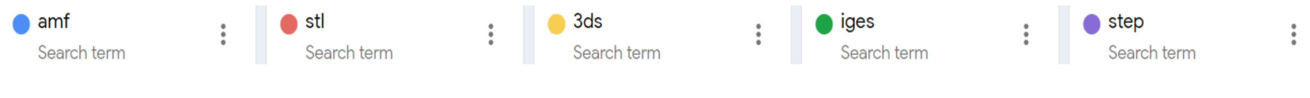
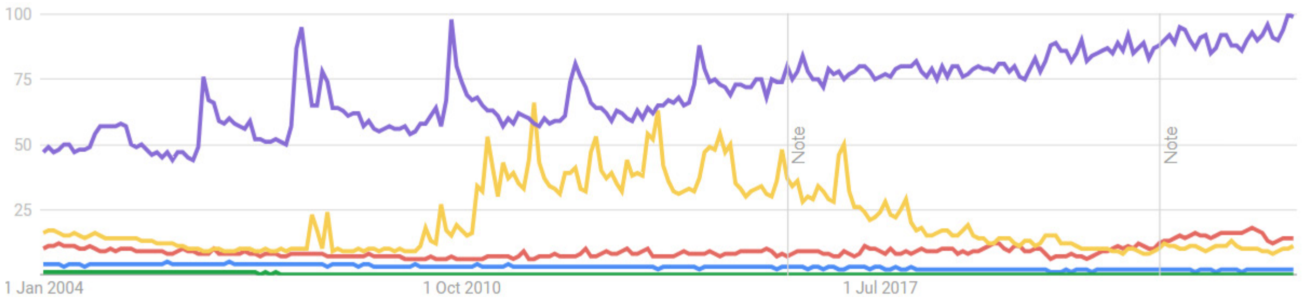
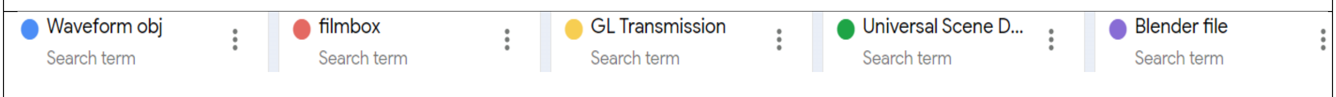
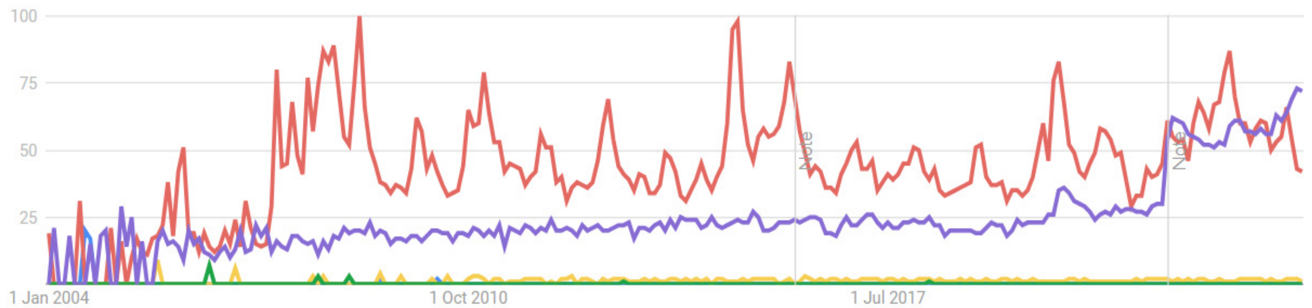
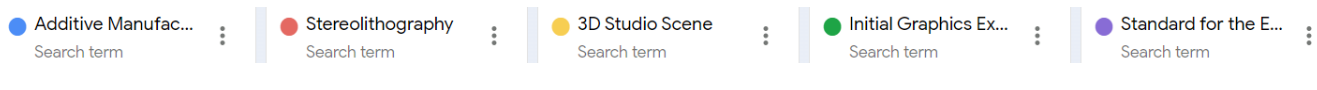
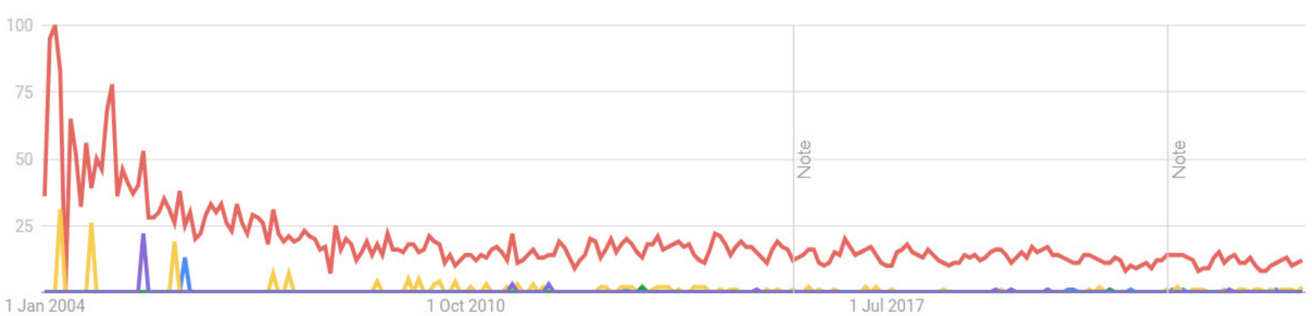
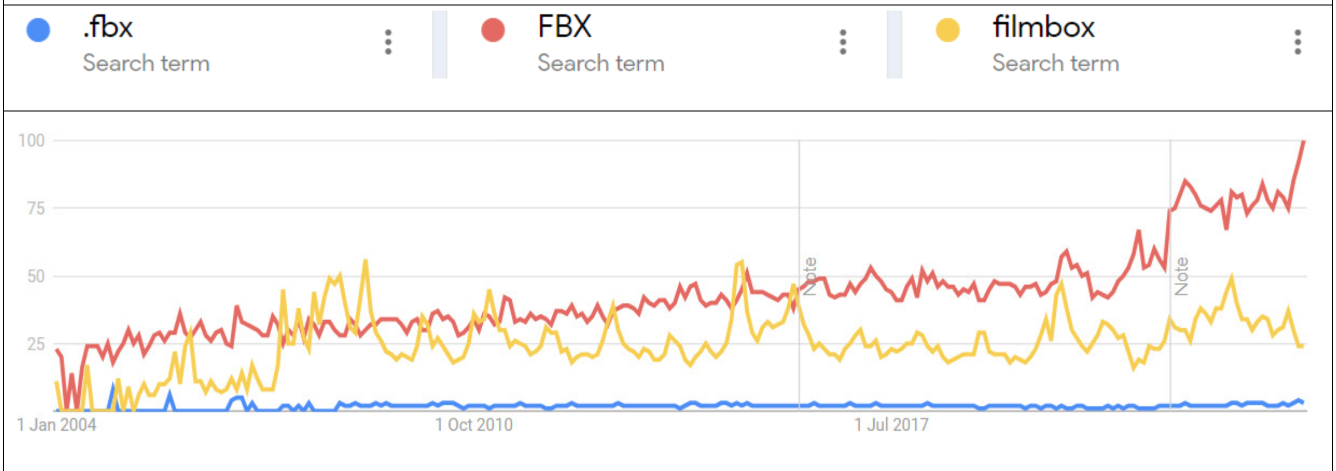
Although google trends are not a perfect measurement of a file formats' popularity, they is the closest to an international database that can give data on the average users' search interest in a given subject. To get a more accurate depiction of the search results, three types of searches have been conducted for each of the formats – using the abbreviation of the format name, using the file extension, and using the full name. The grouped trends are also investigated, but the data is skewed in a way that makes it difficult to analyze without bias.

Table 1. Google trends results for different 3D file formats

File format search terms **Search query (as a hyperlink)** **Color information** **Graph of popularity (2004-2024)**
.obj, .fbx, .gltf, .usd, .blend
https://trends.google.com/trends/explore?date=all&q=.obj,.fbx,.gltf,.usd,.blend&hl=en-GB

.amf, .stl, .3ds, .igs, .step
https://trends.google.com/trends/explore?date=all&q=.amf,.stl,.3ds,.igs,.step&hl=en-GB

obj, fbx, gltf, usdz, blend
https://trends.google.com/trends/explore?date=all&q=obj,fbx,gltf,usdz,blend&hl=en-GB


File format search terms **Search query (as a hyperlink)** **Color information** **Graph of popularity (2004-2024)**
amf, stl, 3ds, iges, step
https://trends.google.com/trends/explore?date=all&q=amf,stl,3ds,iges,step&hl=en-GB


Waveform obj, filmbox, GL Transmission, Universal Scene Descriptor, Blender file
https://trends.google.com/trends/explore?date=all&q=Waveform%20obj,filmbox,GL%20Transmission,Universal%20Scene%20Descriptor,Blender%20file&hl=en-GB


Additive Manufacturing format, Stereolithography, 3D Studio Scene, Initial Graphics Exchange Specification, Standard for the Exchange for Product Data
https://trends.google.com/trends/explore?date=all&q=Additive%20Manufacturing%20format,Stereolithography,3D%20Studio%20Scene,Initial%20Graphics%20Exchange%20Specification,Standard%20for%20the%20Exchange%20for%20Product%20Data&hl=en-GB



File format search terms **Search query (as a hyperlink)** **Color information** **Graph of popularity (2004-2024)**
.obj, obj, Waveform obj
https://trends.google.com/trends/explore?date=all&q=.obj,obj,Waveform%20obj&hl=en-GB

.fbx, FBX, filmbox
https://trends.google.com/trends/explore?date=all&q=.fbx,FBX,filmbox&hl=en-GB

.gltf, gltf, GL Transmission
https://trends.google.com/trends/explore?date=all&q=.gltf,gltf,GL%20Transmission&hl=en-GB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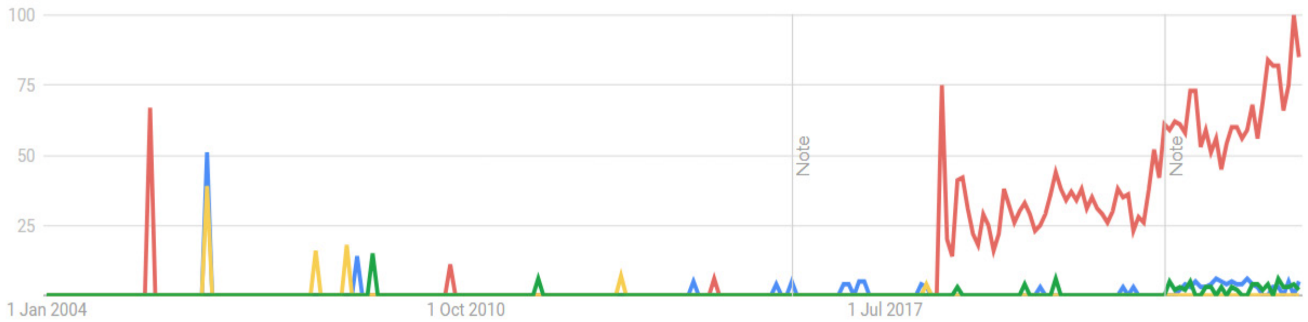
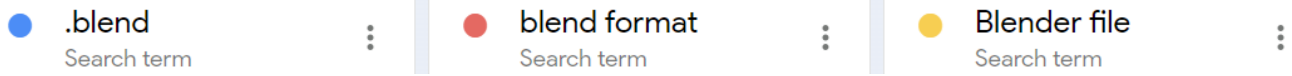
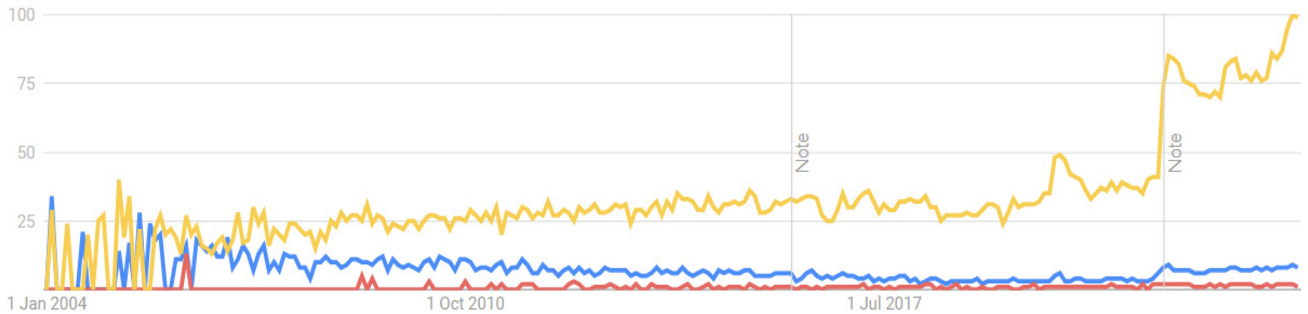
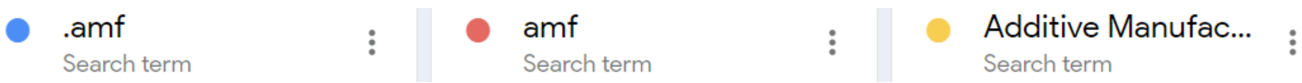
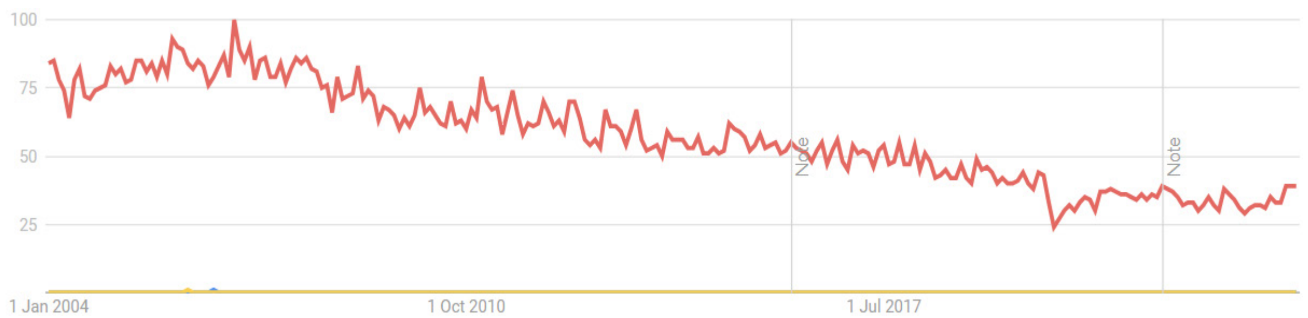
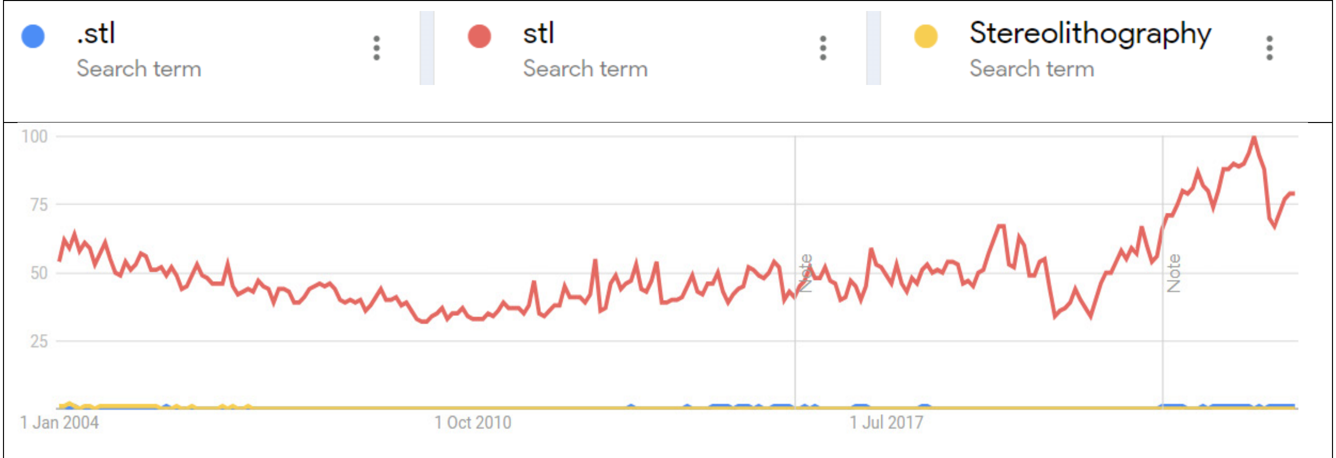
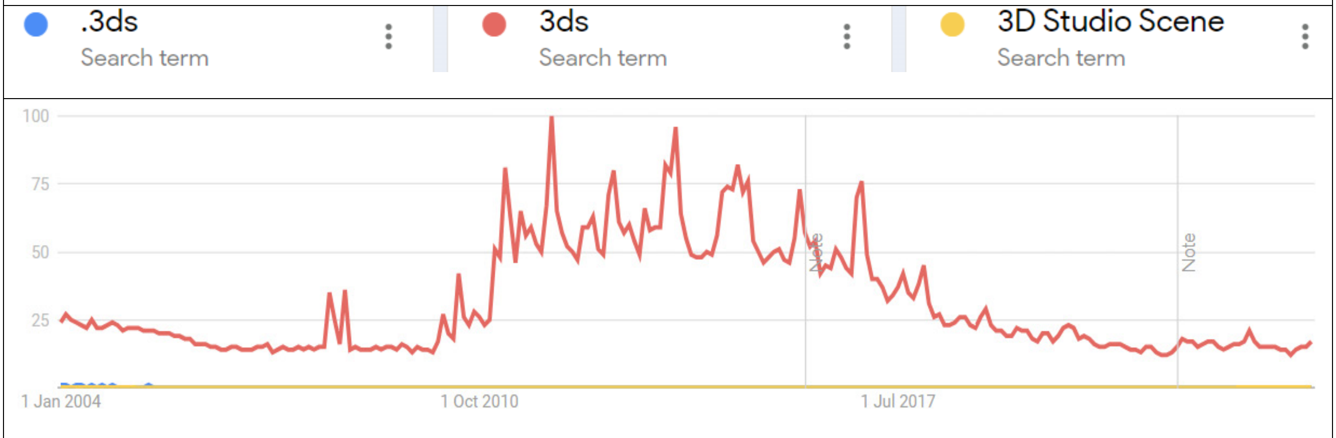
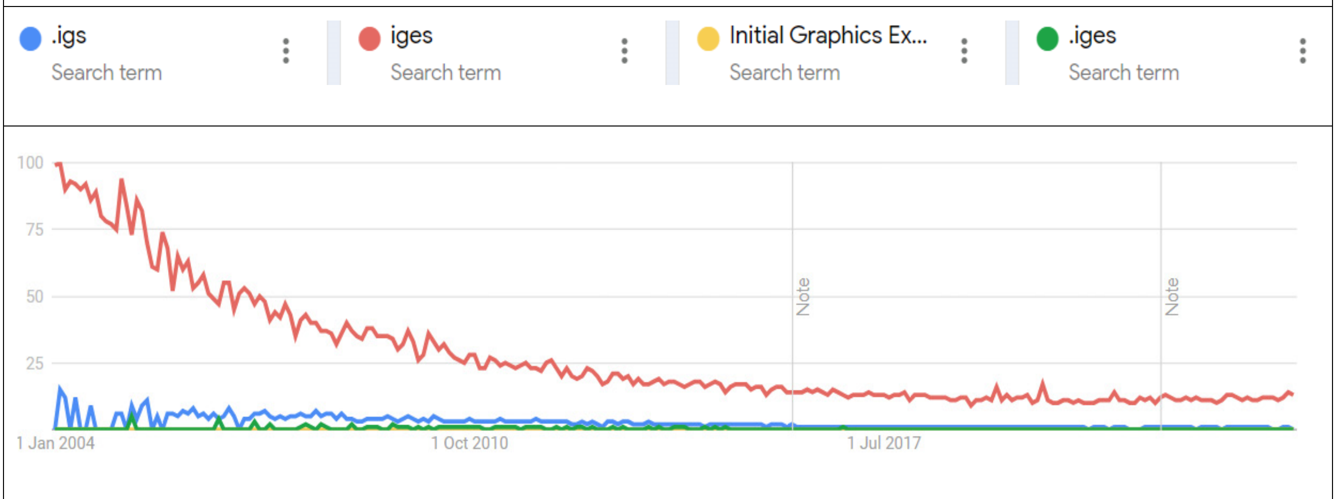
File format search terms Search query (as a hyperlink) Color information Graph of popularity (2004-2024)
.usd, .usdz, usdz, Universal Scene Descriptor
https://trends.google.com/trends/explore?date=all&q=.usd,usdz,Universal%20Scene%20Descriptor,.usdz&hl=en-GB


.blend, blend format, Blender file
https://trends.google.com/trends/explore?date=all&q=.blend,blend%20format,Blender%20file&hl=en-GB


.amf, amf, Additive Manufacturing format
https://trends.google.com/trends/explore?date=all&q=.amf,amf,Additive%20Manufacturing%20format&hl=en-GB



File format search terms **Search query (as a hyperlink)** **Color information** **Graph of popularity (2004-2024)**
.stl, stl, Stereolithography
https://trends.google.com/trends/explore?date=all&q=.stl,stl,Stereolithography&hl=en-GB

.3ds, 3ds, 3D Studio Scene
https://trends.google.com/trends/explore?date=all&q=.3ds,3ds,3D%20Studio%20Scene&hl=en-GB

.igs, .iges, iges, Initial Graphics Exchange Specification
https://trends.google.com/trends/explore?date=all&q=.igs,iges,Initial%20Graphics%20Exchange%20Specification,.iges&hl=en-GB


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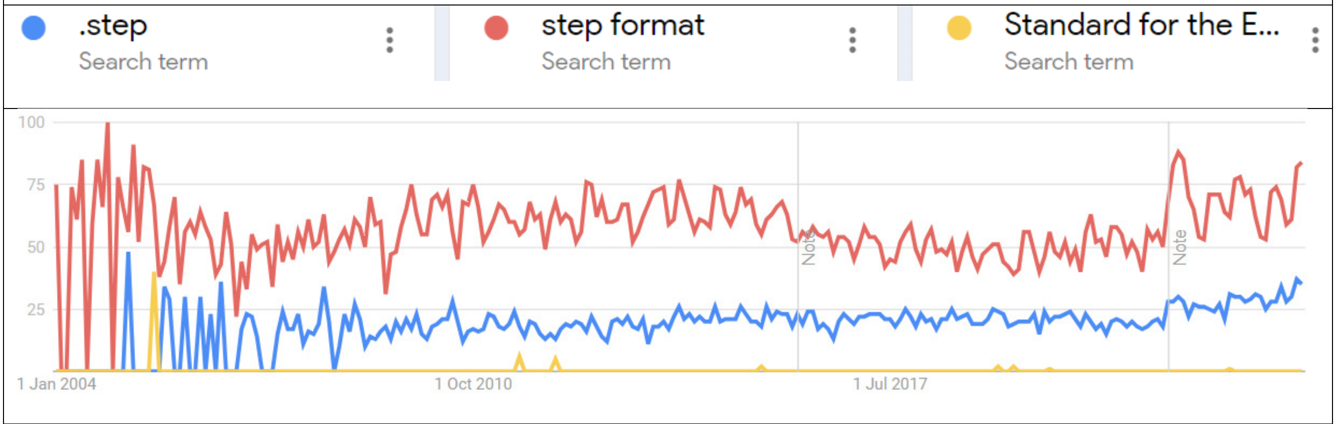
File format search terms **Search query (as a hyperlink)** **Color information** **Graph of popularity (2004-2024)**
.step, step format, Standard for the Exchange for Product Data
https://trends.google.com/trends/explore?date=all&q=.step,step%20format,Standard%20for%20the%20Exchange%20for%20Product%20Data&hl=en-GB


The search engine data groups can be seen in Table 1. The first part of the table is showing formats grouped by 5 for each of the three chosen search styles. The second part contains the grouped formats for each of their three search variations.

Results are interesting in showcasing how the average person stopped searching for file extensions and started searching for the file formats themselves.

Several of the formats show decline in search activity over time – IGES, AMF and 3DS, while STEP notes no increase or decrease, and all the other formats show an increase in search interest. An interesting pattern has been observed - January usually contains peaks for search activities for 3D file formats. After careful consideration a research methodology was created.

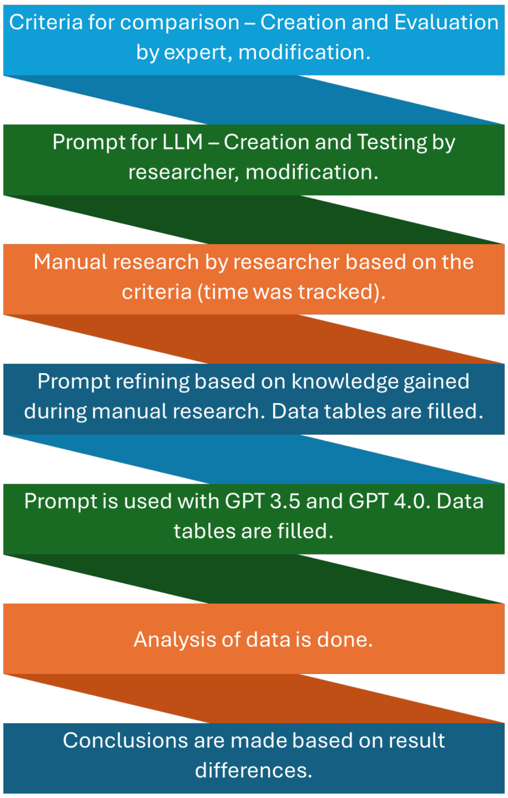


Figure 1. Methodology for researching 3D file format differences using manual research and comparing to LLM summarization

Several steps have been defined and later followed during the process of format reviewing; they can be seen in Figure 1.

Table 2. Criteria for comparison

Criterium	Short description	Expert notes and opinions
File Size	Compare the sizes of the files in each format to understand the compression efficiency and overall file size impact.	In the industry - file size matters not in terms of memory storage in bytes. The 3D objects and their stored information affect the amount of time it takes to open and interpret them. Opening a single STEP file can take hours for example, it is a problem with the processing power required for understanding the complicated geometry of multiple objects. The big files contain multiple objects and complicated geometry, and they often require additional server processing power to access and understand them.
Quality	Evaluate the ability of the format to preserve the details and accuracy of the 3D object during storage and subsequent rendering.	If "quality" is understood as as the ability to have a PDM (Product data management) system divide and regenerate a 3D file, that would be reasonable. It is an industry practice to have a file safely secured in different locations. The percentage of the file that needs to be present for it to be regenerated from its own pieces is an important metric for security.
Compatibility	Assess the level of compatibility with different software applications, operating systems, and hardware platforms.	It is important to have a definition for compatibility in detail, as companies are required to be able to produce parts of old machines for many years after their lifecycle has been completed. This necessitates the continued support of many versions of software, as well as keeping very old files openable. The backward compatibility problem is expensive, which makes this criterium obligatory.
Compression	Analyze the compression algorithms used by each format to determine how effectively they reduce file size while maintaining quality.	In the industry it is often forbidden to archive and compress files in any way, as that may corrupt or irreparably damage an important workflow item. Compression is usually important in film and game creation, where parts of the products are allowed to be of lower quality.
Parameters	Examine the format's ability to store various parameters, such as texture mapping, material properties, animation data, and interactive features.	Used by special software products that work with parameters and can extract parts of a file for a different workflow. For example, the texture of an object can be extracted from a file and used by a design team that will create a cover for a machine. This separability is a workflow necessity, and it is valued in the industry.
Metadata	Assess the format's capability to store metadata, such as authorship information, object descriptions, and copyright details.	When using ERP and PDM systems, metadata is used in the entire process for workflow management. It provides essential information that can be used to control almost every single industrial process. Documentation systems are heavily reliant on the correct metadata present for each file.
Openness	Consider whether the format is open and publicly documented, allowing developers to freely implement support for the format.	Even in the case of entirely proprietary file formats, there may be companies that are called "gold partners", which are creating software for opening and editing those formats. It is an important criterium to take note of, especially if a format is well standardized and open, as that may be a positive or a negative depending on the use-case of a company.
Industry Adoption	Evaluate the popularity and wide usage of the format among professionals in the 3D modeling, animation, and gaming industries.	Highly dependent on chosen workflow.
Lossless/ Lossy	Differentiate between formats that offer lossless or lossy compression algorithms, depending on the requirement for data preservation.	In the industry formats are designed to be lossless, as high quality is imperative.
Animation Support	Examine the format's ability to store complex animations, including kinematics, skeletal animations, and morph targets.	Some CAD software (like SolidWorks) requires the use of special engines in order to animate objects.

All the criteria have been approved by the expert, and each of them has received additional information in the form of notes, as seen on Table 2. GPT4 had an issue with remembering what it was doing during its file format research, so the prompt had to be sent in two separate conversations in order to get the desirable result. The prompt that was used to fill data in Table 3. and Table 6. was crafted as follows: "Please crawl the internet and generate a table that contains the following file formats as rows: ALL 3D FORMATS FOR THIS CONVERSATION; and the following columns: Format, File Size, Quality, Compatibility, Compression, Parameters, Metadata (information), Openness, Industry Adoption, Lossless/Lossy, Animation Support.

Each table row should be filled with data for the 3d file format based on the knowledge you have crawled on the internet. Include your sources. Note that you should use LOW MEDIUM or HIGH to denote the level for each criterium. The exceptions are the Lossless/lossy and Animation support columns, where you should use YES and NO, as they are binary criteria. More thorough descriptions of each criterium are given as follows: DESCRIPTION OF ALL CRITERIA". Due to LLM memory constraints, two separate conversations were to complete the GPT4 research. Two separate conversations were also used to verify the hallucinations of GPT3.5.

Table 3. File format data – manual research and LLM search (respective references are in Table 5 and Table 4)

Format Abbreviation File extension	**Data gathered by manual research (sources are in Table 5)**	**Data generated by an LLM (GPT4) by crawling the internet (sources are in Table 4)**
OBJ (Waveform obj) .obj	3D geometry information, older and more common format, mainly used to export objects, dated material definition [r1]. Can contain MTL with texture/materials if exported correctly, CAN be 3D printed [r2]. Supports multiple objects in one file, supports unit space, lighter weight, standard for game engines in the gaming industry [r1] Last currently known edition [r3] Examples [r4] Specification [r5], [r6]	Quality: High, due to its ability to accurately represent 3D geometry, including vertices, texture coordinates, and normals.[g1][g2] Compatibility: High, as OBJ is supported almost universally across 3D software for both import and export functions. Parameters: High, with support for detailed geometry, including vertices, textures, normals, and various geometric and freeform shapes.[g3] Metadata: Low, as the format does not inherently support embedded structured metadata beyond basic comments within the file.[g2] Openness: High, given its origins and widespread adoption, although the legal status of the specification might be considered proprietary to Autodesk due to mergers and acquisitions.[g3] Industry Adoption: High, with wide use in 3D printing, video games, online product information, and professional disciplines like archaeology and medicine.[g3] Compression: Not applicable, as the format does not include built-in compression mechanisms. It is a plaintext format that can be compressed with external tools but does not have inherent compression.[g2]
FBX (Filmbox) .fbx	Similar to OBJ but can include animation; used in VFX – gaming and film; owned by Autodesk, supported in rendering engines. Supported by current game-engines in VFX and gaming, widely supported, contains more details than OBJ [r1]. Specification [r7]	Quality: FBX is known for supporting high-quality 3D data interchange, including motion, audio, and video data alongside 2D and 3D elements.[g4] Compatibility: Highly compatible with Autodesk's and other third-party 3D animation tools, ensuring smooth workflows across different platforms.[g5] Parameters: FBX supports a wide range of parameters including 3D models, animations, and other assets which is essential for film production, game development, and advertising industries.[g5][g6] Openness: While FBX is a proprietary format owned by Autodesk, it offers SDKs for C++ and Python to facilitate reading, writing, and converting FBX files, suggesting a somewhat closed but accessible system.[g4][g6] Industry Adoption: Widely adopted in various industries for its interoperability between major 3D animation software, making it a standard for asset exchange.[g4][g5][g6] Animation Support: Yes, FBX was specifically designed to support complex animations including motion capture data, making it suitable for high-end animation projects.[g4]

glTF (GL Transmission Format) .glTF, .glb	Open-source alternative to FBX. Used in native web apps, well documented and modern. Supports static models, moving scenes and animation. Optimized for WEB. Supported by newer and upcoming 3D applications [r1]. Specification is well defined [r8].	File Size: glTF is known for its compact file sizes, which are achieved through efficient encoding and optional compression extensions like Draco for mesh compression and KTX 2.0 for texture compression.[g7][g8] Quality: Provides high-quality representations of 3D scenes and models, supporting advanced features like physically based rendering (PBR) materials, enabling realistic appearances.[g7] Compatibility: With widespread industry adoption and support from a variety of software and platforms, glTF ensures high compatibility. It is used by engines like Godot and in a variety of applications including web browsers through WebGL engines like Three.js, Babylon.js, and others.[g7][g8] Compression: Offers native and extension-based compression mechanisms, significantly reducing file sizes and improving loading times without compromising quality.[g7] Parameters: Supports extensive parameters for 3D models including PBR materials, animations, skins, and more, allowing for detailed and expressive 3D assets.[g8] Openness: As an open standard developed by the Khronos Group, glTF is fully accessible and extensible, encouraging innovation and ensuring long-term viability.[g8] Industry Adoption: Adopted as the ISO/IEC 12113:2022 International Standard and used by the Smithsonian Institution for their Open Access Initiative, glTF's adoption is broad and includes significant contributions to 3D commerce and virtual reality.[g7]
USD/USDZ (Universal Scene Descriptor) .usd, .usdz	Fast and efficient data storage, compatible with PBR (physically based rendering) materials, latest shading standards. USD - polygonal file format, open-source (Pixar), geometric, material, scene and animation data [r1]. USDZ – proprietary (Apple/Pixar) for AR Specification is extensive [r9].	Quality: USD is designed for high-quality 3D computer graphics interchange focusing on collaboration, non-destructive editing, and supporting multiple views and opinions about graphics data.[g9] Compatibility: USD boasts wide support across many industries, including visual effects, architecture, design, robotics, and CAD. It is used in various digital content creation applications like 3ds Max, Autodesk Fusion 360, Blender, Cinema 4D, Houdini, Maya, and more, indicating high compatibility.[g9][g10] Parameters: The USD file format supports a comprehensive set of parameters for 3D graphics representation, offering flexibility in describing complex scenes and animations.[g10] Openness: Developed by Pixar and published as open-source software, USD is highly open, promoting standardization, development, evolution, and growth through the Alliance for OpenUSD (AOUSD) formed by major industry players including Pixar, Adobe, Apple, Autodesk, and NVIDIA.[g9][g11] Industry Adoption: USD's design and features have positioned it as a cornerstone for 3D content creation and interchange, with its adoption for the efficient transmission and loading of 3D scenes by applications demonstrating its high industry adoption.[g11]
BLEND (Blender file format) .blend	Default Blender format, stores 3D scene data, models, materials, textures and animations [r11]. Stored in binary file format, contains relationships between objects and scene. Uses hierarchical structures for the information. Supports exporting to other file formats such as FBX, OBJ, Collada etc. Proprietary format. [r11]	Quality: BLEND files preserve high-quality details of 3D scenes including models, materials, textures, and animations, making no compromises on the integrity of digital artwork.[g12] Compatibility: While BLEND files are specifically designed for Blender, the software itself supports a broad range of other file formats, enabling users to import and export content across various applications.[g13] Parameters: These files contain comprehensive scene data including but not limited to 3D models, textures, animations, and Blender-specific settings, providing a wide array of parameters for detailed 3D art creation and animation.[g12] Openness: As Blender is an open-source project under the GNU General Public License (GPL), it ensures that the BLEND file format, along with the software's source code, remains freely available and modifiable. Blender emphasizes open development and contribution, guaranteeing access to future software versions as Free Software.[g14] Industry Adoption: Given Blender's comprehensive feature set and no cost for access, it has been widely adopted across various industries for 3D modeling, animation, and rendering tasks. The versatility and quality of the BLEND format are testament to its broad use by professionals and enthusiasts alike.[no source provided]

AMF (Additive Manufacturing) .amf	Utilized in 3D printing, has XML descriptions of the 3D object, its materials, texture, constellation and metadata [r11]. Contains geometry, color, and material. Can contain multiple objects arranged in a constellation, or multiple constellations, and arranges them in a pattern for printing. [r11]	Quality and Parameters: AMF is capable of storing detailed information about objects' shape, color, and material, allowing for a high-quality representation. This XML-based format also supports complex structures such as curved triangles, enhancing geometric fidelity.[g15] Compatibility: As an ISO standard (52915), AMF is designed for wide compatibility across CAD software, aimed at describing items for 3D printing with enhanced features not available in STL, such as color and texture.[g16][g17] Compression: AMF files can be stored in either plain text or compressed form, with compression significantly reducing file size, often making them about half the size of equivalent compressed binary STL files.[g15] Metadata: AMF files contain metadata for objects, including authorship, copyright, and arrangement in space, providing detailed information that can be useful in various professional settings.[g16] Openness: Created by ASTM and recognized as an official ISO standard, AMF promotes non-proprietary, open standards for 3D printing, ensuring accessibility and interoperability.[g15][g16] Industry Adoption: Although AMF addresses many limitations of the STL format and is supported by major CAD applications, its adoption is still growing. It offers significant improvements for additive manufacturing, making it an important format for future 3D printing and manufacturing technologies.[g17]
STL (Stereolithography) .stl	Utilized in 3D printing, rapid prototyping and computer-aided manufacturing. Encodes an approximate surface geometry of a 3D model using a triangular mesh [r12]. Contains only the geometry of the model, supports both ascii and binary file formats, extremely popular and widespread. Doesn't contain color information. The oldest publicly available format for 3D printing – with the advantages of being a proven and widely supported format, and the disadvantages of lacking modern features. [r11]	Quality and Parameters: STL format is designed for simplicity, using triangles to approximate the surfaces of 3D objects. This approach may not perfectly represent curved surfaces, which can lead to larger file sizes as the complexity increases to maintain fidelity.[g18] Compatibility: STL files are widely supported by a variety of software for 3D scanning, printing, rapid prototyping, and computer-aided manufacturing. Most 3D scanning hardware or software can output in STL format, making it a standard in the industry.[g19] Metadata: STL files generally do not support metadata, such as authorship or copyright information, which can be a limitation for some applications.[g20] Openness: STL is an openly documented format with no concerns about patents or licensing, which has contributed to its widespread adoption across different applications.[g19] Industry Adoption: Despite its limitations, the STL format is considered the standard for 3D printing due to its simplicity and wide compatibility. It's supported by almost all 3D printers and is commonly used for rapid prototyping.[g20]
IGES (Initial Graphics Exchange Specification) .igs, .iges	Well standardized **Error! Reference source not found.** old military format used in engineering. Contains precise geometrical data [r12]. No longer developed – succeeded by STEP. Supports colors, but does not support textures, animation and material types [r12]. Extremely popular and widely adopted – it is supported by all popular CAD software. Recommended for beginners.	File Size: Generally HIGH due to its verbose nature and detailed representation.[g21][g22] Quality: HIGH, capable of preserving complex geometries and structures with accuracy.[g21][g22] Compatibility: HIGH, widely supported across different CAD systems, especially for traditional engineering drawings.[g21][g23] Compression: Not specifically mentioned, but the file format's design doesn't emphasize compression, suggesting LOW efficiency.[g21] Parameters: HIGH, supports a wide range of parameters, including 2D and 3D designs.[g23] Metadata: MEDIUM, capable of storing metadata like authorship but limited by lack of support for modern Unicode character encoding.[g21] Openness: MEDIUM, while widely used and supported, the specifics of the format can be complex and not entirely open.[g21][g22] Industry Adoption: HIGH, remains relevant for legacy systems and interoperability standards.[g22] Lossless/Lossy: YES, the format is designed to be lossless to ensure data integrity. [*General knowledge based on file format characteristics*] Animation Support: NO, IGES is primarily focused on static 3D models and CAD drawings. [*General understanding of format capabilities*]

STEP (Standard for the Exchange for Product Data) .stp, .step	Well standardized 0 widely used in engineering. Contains the same information IGES contains, and expands on it by including materials, texture, topology and others [1r2]. Supports more information than IGES, but not as widespread. Very detailed and can be easily converted to other 3D file formats. Very dimensionally accurate, which is extremely important in engineering [r13].	File Size: MEDIUM to HIGH, designed to be comprehensive but can result in larger files due to detailed data representation.[g24][g25] Quality: HIGH, ensures high fidelity and accuracy in representing 3D models and assemblies.[g25][g26] Compatibility: HIGH, established as the de facto standard for 3D data exchange, supported by nearly all CAD applications.[g25] Compression: LOW, the text-based nature and detailed representation contribute to larger file sizes without specific mechanisms for compression.[g25] Parameters: HIGH, supports a vast array of data types and parameters, from basic geometries to complex assemblies and metadata.[g25] Metadata: HIGH, excellent support for metadata including PMI, ensuring comprehensive data representation.[g25] Openness: MEDIUM, while STEP is an ISO standard, access to some parts of the specification may require payment.[g24] Industry Adoption: HIGH, widely used across various industries for its interoperability and detailed data support.[g25] Lossless/Lossy: YES, the format is inherently designed to be lossless to maintain the integrity of the 3D data. [*General knowledge based on file format characteristics*] Animation Support: NO, like IGES, STEP focuses on static models and does not inherently support animation. [*General understanding of format capabilities*]
DAE, Collada (Digital Asset Exchange File) .dae	Contains an XML schema. The format was created with the intent to be standardized and saw a wide adoption for a time [r12, r14]. Supports geometry, color, textures, animation, kinematics and physics. Neutral format designed for exchangeability between tools in workflows [r14]. Reliable format, but superseded by other formats [r12].	File Size: The COLLADA format, and by extension DAE files, can vary in size. They are designed to encapsulate a wide range of digital assets including 3D models, animations, and textures, which might result in MEDIUM to HIGH file sizes depending on the complexity and content of the digital asset.[g27][g28][g29] Quality: HIGH, as DAE files are capable of containing detailed 3D models with complex geometries, textures, and animations, ensuring high fidelity in visual quality.[g27][g28][g29] Compatibility: HIGH, with broad support across a variety of graphics and 3D modeling applications. Initially developed by Sony and now maintained by the Khronos Group, it is designed for ease of exchange between different software.[g28][g30] Compression: Not explicitly detailed in the sources, suggesting that while DAE files can efficiently store complex data, they might not employ specific compression techniques, hinting at a LOW to MEDIUM compression efficiency. [*General understanding of format capabilities*] Parameters: HIGH, the format supports a wide array of parameters including geometry, shaders, physics, and animations. This extensive support is part of its design to facilitate comprehensive encoding of visual scenes.[g27][g30] Metadata: HIGH, given its XML-based structure, DAE files can include a significant amount of metadata about the 3D assets, including but not limited to creator information, source data, and more.[g27][g28] Openness: HIGH, as COLLADA is an open standard, publicly available and designed to be an interoperable format between various digital content creation (DCC) tools and 3D applications.[g28][g30] Industry Adoption: HIGH, widely used in the 3D modeling and gaming industries for exchanging digital assets due to its flexibility and support for a broad range of 3D data types.[g28][g30] Lossless/Lossy: YES for lossless, as the format's design focuses on the accurate representation of digital assets without quality degradation. [*General understanding of format capabilities*] Animation Support: YES, DAE files support complex animations, making it suitable for detailed visual effects and simulations in addition to static 3D models.[g27][g30]

3DS (3D Studio Scene) .3ds	An extremely well adopted format in engineering, manufacturing, architecture and education. Uses triangular mesh. Stores color, textures, material and others. Does not support directional light sources. Supplemented by the MAX format (or PRJ format) for specific software [r12].	File Size: 3DS files can vary in size, primarily depending on the complexity of the 3D objects they contain. The format is binary and stores mesh data, material attributes, and other scene data compactly, but because of some limitations in the format, it might not always be the most efficient in terms of storage, especially for very complex models.[g31] Quality: HIGH, as 3DS files are capable of storing detailed 3D models including mesh data, material attributes, bitmap references, and lighting information. However, the format has certain limitations, such as all meshes must be composed of triangles, which might affect the final quality and representation of complex geometries.[g32] Compatibility: HIGH with many 3D applications and CAD software supporting the 3DS format due to its long history and association with Autodesk's 3D Studio and 3ds Max. Despite being somewhat outdated, its support across various platforms makes it a versatile choice for 3D model exchange.[g31] [g33] Compression: Not explicitly detailed in the sources, but as a binary format that packs data into chunks, it might offer moderate compression. However, its method of storing certain types of data, like texture filenames, may not be the most space-efficient due to format restrictions.[g32] Parameters: MEDIUM, supports essential 3D data including meshes, materials, and lighting, but lacks support for more advanced parameters and settings found in newer formats. It also doesn't support directional light sources and has limitations on object naming lengths.[g32] Metadata: LOW to MEDIUM, 3DS files store necessary information for 3D rendering but lack comprehensive metadata capabilities, especially for modern uses that might require extensive data about the model, its creation, and its intended use.[g32] Openness: MEDIUM, the format is widely recognized and supported by many applications, but it's a proprietary format developed by Autodesk, which may limit its openness compared to fully open and community-maintained formats.[g31] Industry Adoption: MEDIUM to HIGH, while newer formats have surpassed the 3DS format in features and efficiency, its legacy support across numerous applications ensures it remains in use, particularly for simpler models or when working within specific software ecosystems.[g31] Lossless/Lossy: The format is generally LOSSLESS for the data it supports; however, it does use smoothing groups instead of accurate vertex normals, which can affect the precision of shading across surfaces.[g32] Animation Support: LIMITED, the format supports basic object animations, but with restrictions. For example, keyframe data can be preserved, but there are limitations regarding the sophistication of animations that can be stored.[g33] [g34]

Researcher and GPT4 references can be seen in the following tables:

Table 4. GPT4 Internet references (references per format are colored in alternating colors for clarity)

Researcher visited reference during manual search	GPT4 internet references (all websites have been last visited on the 23rd of March 2024 to confirm validity)
YES	[g1] https://en.wikipedia.org/wiki/Wavefront_.obj_file
YES	[g2] https://www.fileformat.info/format/wavefrontobj/egff.htm
YES	[g3] https://www.loc.gov/preservation/digital/formats/fdd/fdd000507.shtml
YES	[g4] https://en.wikipedia.org/wiki/FBX
YES	[g5] https://www.autodesk.com/products/fbx/overview
YES	[g6] https://docs.fileformat.com/3d/fbx/
YES	[g7] https://en.wikipedia.org/wiki/GlTF
YES	[g8] https://docs.fileformat.com/3d/gltf/
YES	[g9] https://en.wikipedia.org/wiki/Universal_Scene_Description
YES	[g10] https://docs.fileformat.com/3d/usd/
NO	[g11] https://developer.nvidia.com/usd
YES	[g12] https://docs.fileformat.com/3d/blend/
NO	[g13] https://all3dp.com/2/blender-file-format-overview/
YES	[g14] https://www.blender.org/support/faq/
YES	[g15] https://en.wikipedia.org/wiki/Additive_manufacturing_file_format
NO	[g16] https://www.xometry.com/resources/3d-printing/amf-file-format/
NO	[g17] https://blog.ansi.org/additive-manufacturing-file-format-amf-iso-52915/
YES	[g18] https://en.wikipedia.org/wiki/STL_(file_format)
YES	[g19] https://www.loc.gov/preservation/digital/formats/fdd/fdd000504.shtml
NO	[g20] https://www.adobe.com/creativecloud/file-types/image/vector/stl-file.html
YES	[g21] https://en.wikipedia.org/wiki/IGES
YES	[g22] https://all3dp.com/2/iges-file-format-simply-explained/
YES	[g23] https://docs.fileformat.com/cad/iges/
NO	[g24] https://en.wikipedia.org/wiki/ISO_10303-21
NO	[g25] https://cadexchanger.com/blog/3d-formats-overview-step/
NO	[g26] https://www.3d-insider.blog/post/the-comprehensive-guide-to-step-file-versatile-3d-data-interchange
YES	[g27] https://docs.fileformat.com/3d/dae/
YES	[g28] https://fileinfo.com/extension/dae
NO	[g29] https://all3dp.com/2/collada-file-dae-file-simply-explained/
YES	[g30] https://en.wikipedia.org/wiki/COLLADA
NO	[g31] https://fileinfo.com/extension/3ds
YES	[g32] https://en.wikipedia.org/wiki/.3ds
NO	[g33] https://help.autodesk.com/view/NAV/2021/ENU/?guid=GUID-FD6947A9-3107-4A0D-82F0-996891180982
NO	[g34] https://support.lumion.com/hc/en-us/articles/360049449114-Model-import-guidelines-for-the-Autodesk-3DS-file-format

Table 4 contains all the websites that GPT4 has visited during the research process. The websites used by GPT4 as sources are: Wikipedia, Fileformat.info, Autodesk.com, fileformat.com, nvidia.com, all3dp.com, blender.org, xometry.com, loc.gov/preservation, codexchanger.com, adobe.com, 3d-insider.blog, blog.ansi.org, fileinfo.com, Lumion.com. A total of 15 sites for 34 references. The most used reference is Wikipedia – 10 times. There are several references which are used only once.

The researcher has visited and read (but not necessarily used) 22 of the 34 GPT4 references during the manual search for information, which puts the researcher at about 64.7% reference coverage. It can be noted that the LLM research provided 12 fresh sources of relevant information that could be used to further enhance the study of 3D file formats. GPT4 seems to be gravitating towards 2-4 sources per file format. There is an overlap between the sources used by the GPT4 model and the ones used by the researcher manually.

Table 5. Manual researcher references

Ref. code	**Manual researcher internet references (all websites have been last visited on the 23rd of March 2024 to confirm validity)**
[r1]	https://www.adobe.com/products/substance3d/discover/3d-files-formats.html
[r2]	https://www.youtube.com/watch?v=Gkjyi-6bl6Q (Understanding 3D File Formats – Joko Engineering)
[r3]	https://www.iana.org/assignments/media-types/model/obj
[r4]	https://people.math.sc.edu/Burkardt/data/obj/obj.html
[r5]	https://www.loc.gov/preservation/digital/formats/fdd/fdd000507.shtml
[r6]	https://www.fileformat.info/format/wavefrontobj/egff.htm
[r7]	https://code.blender.org/2013/08/fbx-binary-file-format-specification/#binary-file-structure
[r8]	https://github.com/KhronosGroup/glTF/blob/main/README.md
[r9]	https://openusd.org/release/spec_usdz.html
[r10]	https://support.apple.com/guide/preview/view-a-universal-scene-description-usd-file-prvwd129f236/mac
[r11]	https://docs.fileformat.com/3d/
[r12]	https://all3dp.com/2/most-common-3d-file-formats-model/
[r13]	https://www.jaycon.com/exporting-3d-files-stl-vs-obj-vs-iges-vs-step/
[r14]	https://fileinfo.com/extension/dae

The references (Table 5) and filling of the table with information about the file formats took the non-expert researcher manually 12 hours over the span of 5 days. The researcher took about 1 hour to do the same using GPT4, and about 2 more hours to format the data in a presentable way. It must be noted that if a researcher spends time to first build a pattern of knowledge recognition and an amount of field knowledge on a research topic first, the use of GPT as a helper is tremendously more beneficial.

There is a high degree of similarity of used Internet references. Ignoring issues of "trustworthiness" of the websites, not checking for circular citations, and same source information, it is incredible how much the LLM has achieved on its own.

It can be concluded that if GPT4s current ability to track data on the Internet improves it will be extremely helpful when doing comparison research. This can also be used to further study its ability to compare the file formats themselves – given enough data. Whether it can be used to analyze and crack proprietary formats and forcefully integrate them into open-source products is another angle that must be considered for the future of licensing and standard property protection. GPT4 cannot analyzeGoogle scholar yet, but it is worth exploring the idea of using it as a helper during similar searches in research documentation – though it should be made abundantly clear that all information should be double checked.

Table 6. Comparison between researcher results, GPT3.5, and GPT4 results

Format by: R/G3.5/G4	File Size	Quality	Compatibility	Compression	Parameters	Metadata (information)	Openness	Industry Adoption	Lossless/Lossy	Animation Support
OBJ	LOW	MEDIUM	HIGH	-	HIGH	-	HIGH	HIGH	LOSSLESS	NO
GPT 3.5	MEDIUM	MEDIUM	HIGH	LOW	HIGH	MEDIUM	HIGH	HIGH	LOSSLESS	YES
GPT 4	-	HIGH	HIGH	NO	HIGH	LOW	HIGH	HIGH	LOSSLESS	NO
FBX	LOW	MEDIUM	HIGH	-	HIGH	-	MEDIUM	HIGH	-	YES
GPT 3.5	MEDIUM	HIGH	HIGH	MEDIUM	HIGH	HIGH	LOW	HIGH	LOSSY	YES
GPT 4	-	HIGH	HIGH	-	HIGH	-	LOW	HIGH	-	YES
GLTF	LOW	HIGH	HIGH	-	HIGH	-	HIGH	HIGH	-	YES
GPT 3.5	MEDIUM	HIGH	HIGH	MEDIUM	HIGH	MEDIUM	HIGH	MEDIUM	LOSSLESS	YES
GPT 4	LOW	HIGH	HIGH	-	HIGH	-	LOW	HIGH	-	YES
USD	LOW	HIGH	MEDIUM	-	HIGH	-	HIGH	MEDIUM	-	YES [r10]
GPT 3.5	HIGH	HIGH	HIGH	MEDIUM	HIGH	HIGH	HIGH	LOW	LOSSLESS	YES
GPT 4	-	HIGH	HIGH	-	HIGH	-	HIGH	HIGH	-	YES
USDZ	LOW	HIGH	MEDIUM?	-	HIGH	-	LOW	MEDIUM	-	YES [r10]
GPT 3.5	HIGH	HIGH	HIGH	MEDIUM	HIGH	HIGH	HIGH	LOW	LOSSLESS	YES
GPT 4	-	HIGH	HIGH	-	HIGH	-	HIGH	HIGH	-	YES
BLEND	LOW	HIGH	HIGH	-	HIGH	-	MEDIUM	MEDIUM	-	YES
GPT 3.5	MEDIUM	HIGH	HIGH	MEDIUM	HIGH	MEDIUM	HIGH	HIGH	LOSSLESS	YES
GPT 4	-	HIGH	MEDIUM	-	HIGH	-	HIGH	HIGH	-	YES
AMF	LOW	HIGH	HIGH	-	HIGH	-	HIGH	MEDIUM	-	NO
GPT 3.5	MEDIUM	HIGH	MEDIUM	MEDIUM	HIGH	MEDIUM	HIGH	MEDIUM	LOSSLESS	YES
GPT 4	LOW	HIGH	HIGH	YES	HIGH	HIGH	HIGH	MEDIUM	-	NO
STL	LOWEST	LOW	HIGH	HIGH	LOW	LOW	HIGH	HIGH	LOSSY	NO
GPT 3.5	LOW	LOW	HIGH	HIGH	LOW	LOW	HIGH	HIGH	LOSSLESS	NO
GPT 4	MEDIUM	MEDIUM	HIGH	NO	LOW	LOW	HIGH	HIGH	-	NO
IGES	LOW	MEDIUM	HIGHEST	-	MEDIUM	LOW	HIGH	HIGH	-	NO
GPT 3.5	HIGH	HIGH	MEDIUM	MEDIUM	HIGH	HIGH	HIGH	LOW	LOSSLESS	YES
GPT 4	HIGH	HIGH	HIGH	-	HIGH	MEDIUM	HIGH	HIGH	LOSSLESS	NO
STEP	MEDIUM	HIGH	HIGH	-	HIGH	HIGH	HIGH	HIGH	-	NO
GPT 3.5	HIGH	HIGH	MEDIUM	MEDIUM	HIGH	HIGH	HIGH	LOW	LOSSLESS	YES
GPT 4	MEDIUM	HIGH	HIGH	LOW	HIGH	HIGH	MEDIUM	HIGH	LOSSLESS	NO
DAE	MEDIUM	HIGH	MEDIUM	-	HIGH	HIGH	HIGH	HIGH	-	YES
GPT 3.5	MEDIUM	LOW	MEDIUM	MEDIUM	LOW	LOW	LOW	MEDIUM	LOSSLESS	YES
GPT 4	-	HIGH	HIGH	-	HIGH	HIGH	HIGH	HIGH	LOSSLESS	YES
3DS	MEDIUM	HIGH	HIGH	-	-	MEDIUM	MEDIUM	HIGH	LOSSLESS	YES
GPT 3.5	MEDIUM	LOW	MEDIUM	LOW	LOW	LOW	LOW	MEDIUM	LOSSY	YES
GPT 4	-	HIGH	HIGH	-	MEDIUM	MEDIUM	MEDIUM	HIGH	LOSSLESS	YES

Criterion has been evaluated according to data gathered in Table 2 where specifications, examples, and other available sources have been described. Each table row has been filled with data for a 3D file format, alternating between manual researcher, GPT3.5 training data result and GPT4 Internet analyzing. Lack of sufficient expertise and criteria which are deemed to be ambiguous by the researcher for a particular format, are denoted in Table 6 by a dash and are colored yellow.

It should be noted that GPT3.5 completely hallucinated its answers based on its training data (this was verified in two separate conversations), making its table rows not only unreliable, but also deceptively well explained when asked about the details, in the typical confidence of AI models. GPT3.5 generates wrong information fast, as was expected.

Given the time frame the researcher could not fill all the cells of the table, because of lack of expertise, and sources. Compression is the most notable criterium that lacks information by the manual researcher.

The file size criterium is ambiguous, and highly dependent on the objects that are in the files.

Comparing the manual research results to the AI suggestions, it can be seen that out of the 10 criteria, for 12 file formats, there are 39 differences. This means that 32.5% of the responses are either different or missing. It should be noted that with the improvement of LLMs and their respective applications, it would be feasible to automate such file comparisons in the near future, as a large amount of manual work is required to check all the different types of formats and their peculiarities.

5. Binary Comparison

Metadata is crucial to industry workflow management – as per expert opinion, in most advanced manufacturing processes, the 3D files have their metadata closely related to documentation and workflow. The different software products track the stages of development and completion of a product, its handling by machinery, its authors and more, depending on its point in the production line.

The same is also true to most 3D file formats outside of CAD systems – metadata can keep relevant information on its creators, time of creation, file format version, software version, dates of modification, and various other data that is specific to each format.

There is a plethora of niche knowledge associated with each file formats' data and how it is manipulated. A multitude of problems can arise from compatibility issues due to different software versions – some of the most serious are total file corruption (meaning enough data has been corrupted that it cannot be regenerated) or hidden errors that are difficult to notice until analyzing the entirety of the objects in a file format.

If the power of LLMs can be leveraged in checking, verifying, converting, and regenerating files based on a specific machine learning training set, that would save time and effort that can be used in other parts of the 3D design and development process.

To understand the differences between file format data templates, a small comparison was made between the binary information on some 3D file formats. A binary editor was used – "010 editor", which allowed the researchers to use specialized "templates" available for open-source 3D file formats and display the data in a comprehensive way.

CAD		
3DS.bt	Parse an 3D Studio MAX scene files	More Info...
Blend.bt	Parsing Blender file	More Info...
FBX.bt	Reading binary .fbx (FilmBox) files structure.	More Info...
GLB.bt	Parse glb Khronos 3D Files	More Info...
LAS.bt	Analysis of point-clouds in LAS-Format	More Info...
Modo.bt	Reads all known chunks in Modo *.lxo, *.lxp. *.lxe and *.lxl 3D files as documented at http://sdk.luxology.com/wiki/File_Formats.	More Info...
MS3D.bt	Parse MilkShape3D v1.8.5 Scene File	More Info...
OrCAD_BRD.bt	Parse OrCAD v2.10 database for PCB files. It probably allowed to any 16-bit OrCad versions 1.xx, 2.xx, 3.xx and 4.xx	More Info...
OrCAD_LIB.bt	Analyse OrCad 3.20a library files.	More Info...
OrCAD_SCH.bt	Analyse drawings and blocks from OrCad 3.20a programs.	More Info...
PCAD45.bt	Parse P-CAD 2.0-4.5 database PCB, PRT, SCH, SYM files	More Info...
Realflow_Bin_Particles.bt	Reads Nextlimit Realflow BIN particle files as per .pdf delivered with Realflow	More Info...
STL.bt	Parse an STL binary file containing 3D geometry (CAD).	More Info...

Figure 2. CAD 3D file formats binary interpretation templates in 010 hex editor

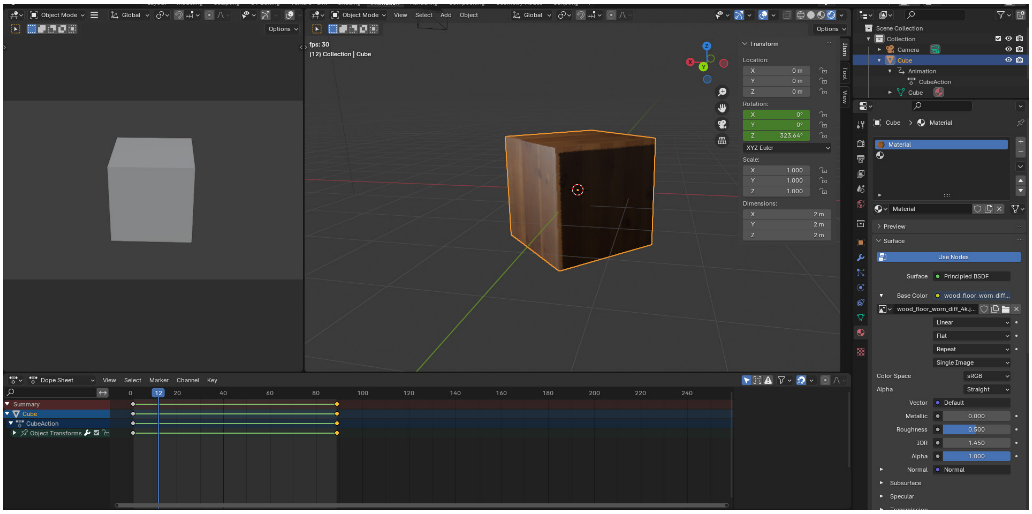


Figure 3. Simple cube with wooden floor texture and an animation added in Blender

As of the beginning of 2024, the list of templates contains the formats seen in Fig. 2. A simple cube was created in Blender (Fig. 3), a wooden floor texture was added, and an animation was applied, so that the cube is rotating for 89 frames (the animation is looped, hence 1 frame has been subtracted to avoid "freezing", as the last and the first and the 90th frame are the same). Blender has incredible tools that are freely available to export to various file formats.

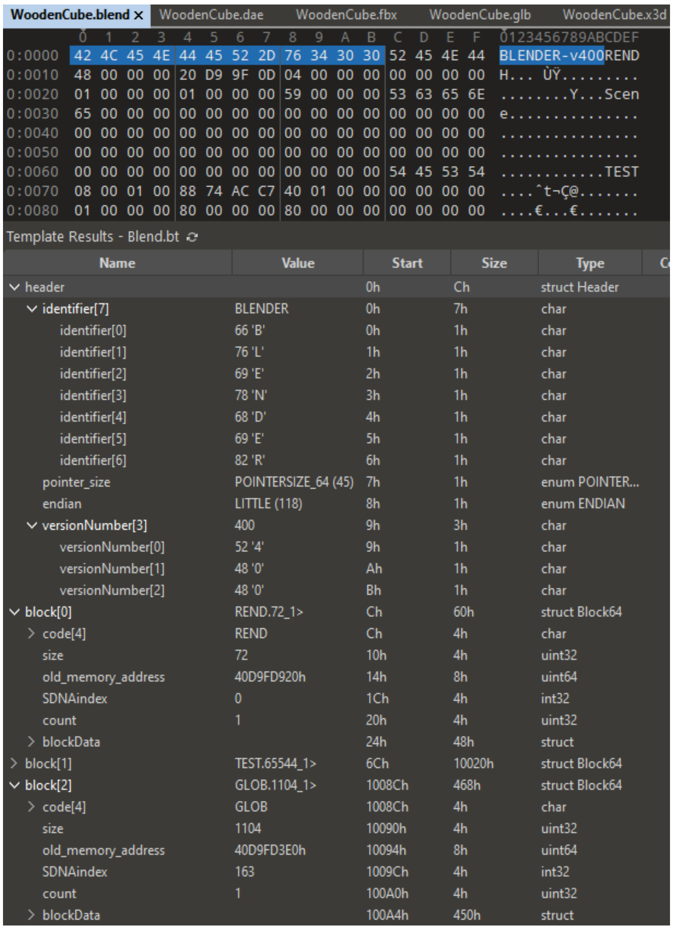


Figure 4. Binary representation of metadata of the .blend file format

Figure 5. XML metadata of the .dae file format

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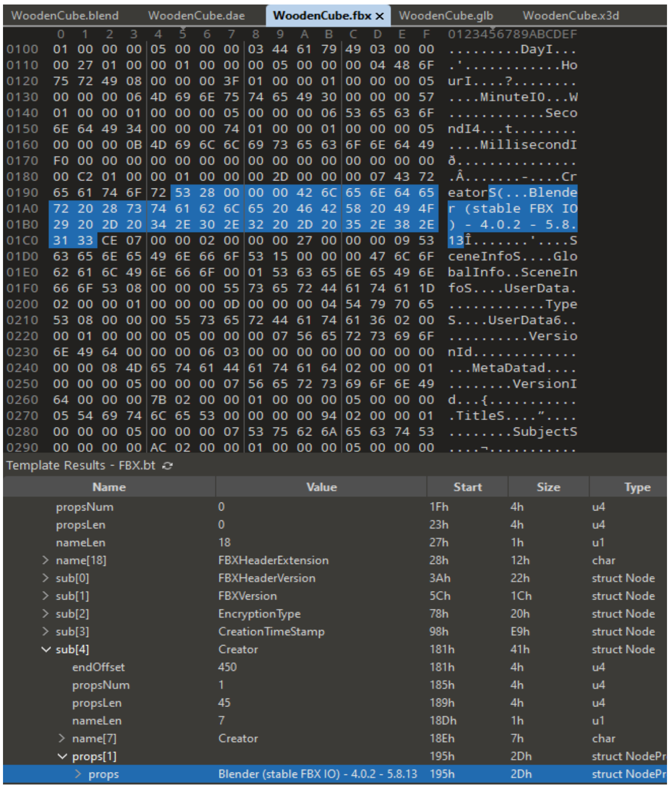

Figure 6. Binary representation of metadata of the .fbx file format

The internal composition of the .blend (Fig. 4), .dae (Fig. 5), .fbx (Fig. 6), .glb (Fig.7) and .x3d (Fig. 8) file formats are displayed. It should be noted that having tools like this one, it is possible to reverse engineer and decode the structure and encoding of proprietary formats, although it is a tedious process – if an object is given a property or a texture for example, then saved/exported, it can be instantly recognized which part of the file has changed and how exactly (LLMs can be used for this type of decoding in the future).

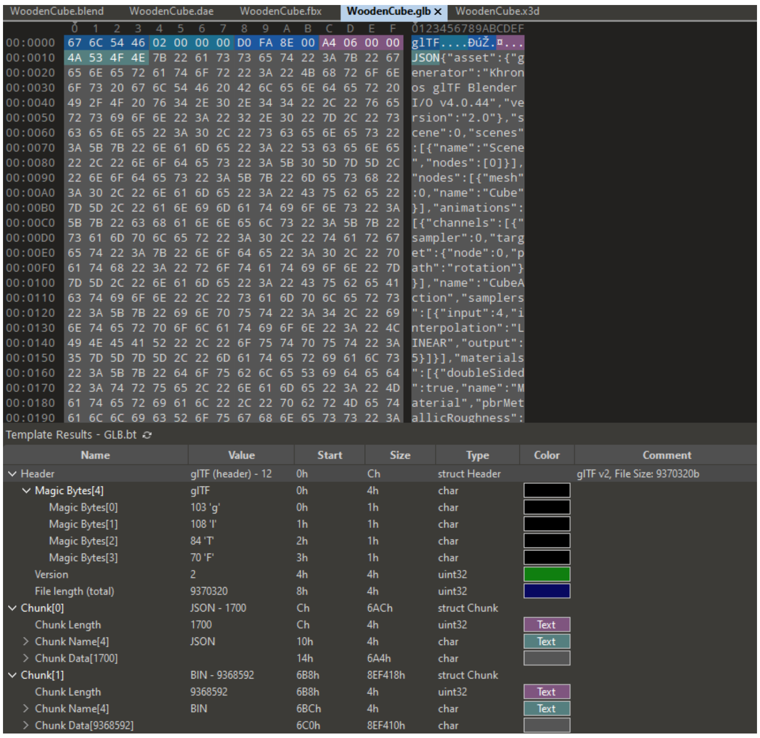

Figure 7. Binary representation of metadata of the .glb file format

Figure 8. XML metadata of the .x3d file format

Proprietary formats are protected by copyright of course, but there is a rare case where that may be necessary, and it merits researchers to know how to achieve this – if the company or the software version of a proprietary product becomes extinct and no documentation is left, the only way is to reverse engineering their legacy data.

6. Conclusion

It can be concluded that a standard needs to be defined, as there are limited ways to get reliable and relevant information about 3D file formats. Most of these formats are proprietary. The comparisons between them are made by experts, and some of them are available freely to the public, but they are often in video format or in blog posts. A great source of information is the Blender documentation, as the people writing the modules and scripts for file conversions are the most adept and experienced at noticing the differences between objects in various file formats.

The GlTF file format is currently the closest to a widely accepted standard. Its definition is thorough and well documented. NVIDIA OMNIVERSE deserves a mention, as it is currently at the forefront of integrating multiple 3D environments, manufacturing workflows, simulations, LLMs and AI.

The world is changing to adapt to increased computational power, which will power AI tools of such magnitude and complication that it is difficult to imagine how the research process will change. Controlled AI and LLMs certainly have a place as assistant tools for researchers to make use of.

In terms of using LLM powered searches to do research on file formats, it should be noted that it must be used as complimentary research, to verify, check, and gather more information. At least at this point in time, the sources it uses are heavily reliant on non-peer-reviewed research – blog posts, Wikipedia, websites. The more that researchers refine the use of such tools, the better they will get at using them, which will be beneficial in the long term. In the field of 3D file formats - with the ever-growing interest in digitization, 3D printing, simulations that use 3D virtual environments (robotics training), workflow changes – it is incredibly useful to have a tool that can be relied upon for the hard work of crawling for information and synthesizing the most important details, as well as comparing differences using a predefined expert-approved criteria. As metadata is extremely important to categorize and use files in workflows, it is important to know and understand how the files differ from each other – their binary representations may be the key to creating a unified 3D file format standard for the future.

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