Evaluation and Analysis of the Features and Applications of 3D Model Platforms

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Abstract. As the 3D printer technology has been enhanced, 3D printers are more affordable and popularized. With the concepts of crowdsourcing, open source and sharing, 3D model platforms have become the highlight of the next wave of 3D printing industry. There are numerous articles on 3D printing technology, hardware and equipment, and materials. However, few articles deal with the topic of 3D model platforms for in-depth investigation. In this study, contents of those models that are available on 7 well-known 3D model platforms and their website functions are evaluated. The evaluation includes 4 primary dimensions which include website description, model file information, website function, and social interaction. These four dimensions are further classified into 22 items for the cross-verification of 3D model platforms. The application features of each 3D model platforms are identified. In addition, the three challenges for the future development of 3D model platforms are concluded as follows. (1) Insufficient format information of the file for download. (2) Unclear intellectual property (IP) licensing status of model files. (3) Security vulnerability of file information.

Keywords: 3D model platforms · 3D printing · Maker

1 Introduction

With the development of open source code, hardware, and community sharing, the maker movement sprang up everywhere. Product manufacturing can be realized not only in factories but also in houses or personal studios. The influence of digital software resources and smart machines on the manufacturing industry has created a new wave of social and technological revolutions [1]. The Internet allows makers to show their own design information and manufacturing knowledge to the world in an easier way. They are able to share design and manufacturing knowledge so that the original barrier between different societies or cultures has disappeared. During this wave of revolution, the most important thing is the creation of digital fabrication tools. These digital fabrication tools are more affordable and their popularization has changed the current working model of our society. Common digital fabrication tools include 3D printer, 3D scanners, laser cutters, digital milling machines, digital guillotines, numerical control (NC) machines, computerized numerical control (CNC) machines, and computer aided manufacturing (CAM) machines. Among them, the development in the 3D Printing technology is fastest and it has a wide range of applications.

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The 3D printing technology originated from the patented 3DPTM process that was invented by the Massachusetts Institute of Technology. Various types of computer aided design (CAD) software can be used to build model files. By utilizing the additive manufacturing approach, a three-dimensional structure is created by the superposition of layers of materials. The inception of the 3D printing technology began in the 1980s. In recent years with the open source trend of the maker movement and some important patented technologies, the fast innovations in the 3D printing technology lead to an era with the embodiment of digital data.

In 2007, the first desktop 3D printer RepRap which adopted the open source code was born. This is an important milestone for the maker movement. After that, affordable 3D printer MakerBot sprang up and it allows makers to realize their creations in an unconstrained style. It means a lot to makers and the effects are just like the personal computer that appeared 30 years ago. It has changed the production and operation model of the manufacturing industry. Common people are able to assess the printing quality, speed, range of printable size, output stability, and price of each model that is available. By selecting a machine that meets personal requirements, everyone can realize his/her dream of fabricating any object freely by 3D printing [2]. The growth in the sales volume of consumer 3D printers below USD 5,000 is huge. The target customers include makers, enterprises, schools, laboratories, and personal studios. The upstream and downstream industries that are related to 3D printing have developed into a big market with a business scale of billions of US dollars around the world and the market keeps growing.

With the advance in technology, the equipment, materials, and software that are used on 3D printers have gradually become mature. The development in makerspace is also rising and flourishing. However, it can be found from the current situation that, most of the users are still confined by the capability of the modeling software when fabricating their creations. Even if they can build a model, they might still encounter problems with the analysis of slicer software, calculation of support material parameters, and the adjustment of printing details. For most of the users, this has become a common bottleneck for beginners who still lack of technical capability (Fig. 1). Moreover, the open source and sharing, crowdsourcing concepts encourage makers to share their own creations. As a result, in addition to the original business of hardware developments, some 3D printing hardware manufacturers also started to build their own database of 3D model files (hereinafter referred to as 3D model platform) in order to assist users in printing their 3D artworks. In addition, 3D modeling software companies and various government organizations also allocate resources in constructing 3D model platforms and related services. In the future, the biggest source of revenue for 3D printing business comes from the 3D model platform, instead of equipment or consumables [3].

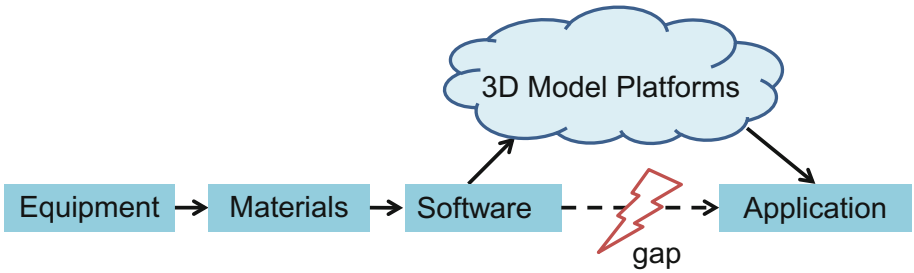


Fig. 1. Emerging 3D model platforms

2 Investigation of 3D Printing Technology

As compared to conventional manufacturing approaches, the advantages of 3D printing technology are as follows. (1) A higher degree of freedom for the structural design: The 3D printing technology can realize the direct printing of complicated structures without considering the problems of cutting or mole release. Therefore, a higher degree of freedom is allowed for designs that use 3D printing technology. (2) A lower cost for small-scale manufacturing: 3D printing technology can save the development cost of tooling/mold and reduce the problem of material wastes during small-scale manufacturing. (3) Rapid forming of custom products: When making a product by 3D printing, the configured precision and the sample size affect the required time for manufacturing. A product can be complete within several hours to a couple of days based on the current technology. The precision of the finished product that is obtained from the additive manufacturing approach is determined by the thickness of the layers for superposition. At the moment, the precision of 3D printed products is generally within the range of 100–200 um. The precision of some 3D printers can be below 10 um [4]. The investigation of 3D printing is generally carried out from four aspects which are respectively technology and equipment, material, software, and printing applications as follows.

2.1 Technology and Equipment

There are more than a dozen of 3D printing technologies depending on their forming techniques. The technologies have been improving and they cover a wide range from basic designs to the production of custom products with high difficulty. Five of the most common forming techniques are summarized as follows [4–7].

1. Fused deposition modeling (FDM): This is the most common technique. The working theory is to heat the raw material to its semi-molten state and squeeze the material to the printing base plate. The material restores to the solid state after it cools down. Repeat this deposition process so that the three-dimensional object will be formed. Since it is required to wait for each layer of material to cool down during printing, this approach could lead to minor misalignments during the deposition of the lower layer of material. Moreover, the raw material could deform a bit during the process of cooling down. However, the material cost of FDM is lower and the required time for producing larger

objects is shorter. The final product is sturdier and it is suitable for models with simple styles and larger industrial mechanical parts.
2. Stereolithography (SLA): Light-cured resins are used as the raw material which is solidified after be cured by laser light. During printing, the laser light irradiates precisely on specific locations in the raw material pool so that the raw material solidified layer by layer. By repeating this process, a three-dimensional object can be stacked up. The final product presents higher precision and better surface quality. Therefore, this technique is suitable for complicated or delicate parts such as crafts, necklaces, or hollow parts.
3. Selective Laser Melting (SLM/DMLS): This forming technique is similar to selective laser sintering (SLS). However, it required a higher laser power since the materials are mainly metal based. Virtually any metal material that can be prepared as small powders can be used as the raw material for the SLM technique.
4. Selective Laser Sintering (SLS): This technique is to utilize the energy from infrared laser beams to sinter metal powders including steel and titanium or thermoplastic macromolecular materials such as nylon or ceramic powders. On the processing platform, a computer is responsible for analysing the coordinate data including points, lines, and surfaces of the 3D model file layer by layer until a complete model file for sintering is acquired. The maintenance cost of such equipment and its consumables are relatively higher as compared to other techniques.

2.2 Printing Materials

Printing materials can be classified into three categories by their characteristics. These three categories include metal materials, non-metal and non-biomaterials, and biomaterials which can be further classified into several sub-categories for different types of printing technologies. Metal materials include various types of metal powders. Non-metal and non-biomaterials include thermoplastic materials such as ABS or PLA, light-cured resins, ceramic powders, gypsum powders, and wax. Common materials that are used by consumer 3D printers include ABS and PLA [8].

2.3 Software

Although the approach used by each 3D forming technique might be different from others, the first step is usually to build the 3D model by CAD software. The 3D model is then sliced in the slicer software so that each slice can depict the inner and outer profile of each section of the 3D model. After that, the profile of each of these slices needs to be converted into G-code parameters in order to configure the printing parameters for the 3D printer. G-code is a set of instructions that are used by numerical control (NC) machines. It can be viewed as the language for an operator to communicate with his/her NC machines. The NC control codes can be manually entered or automatically generated by computer software so that the cutting tools of a NC machine will move in a configured way [6]. The final step is to check the model file for any broken surface or insufficient support structure so that the model won't collapse during printing.

Modeling Software. As 3D printing is getting more popular, a diversity of modeling software packages has appeared. The modeling software can be classified into five categories which include basic stack-up, parts design, model animation design, sculpture modeling, and architecture modeling. According to our own experience and the discussions on 3D printing communities, the features of different 3D modeling software packages that are commonly used by makers, schools, and the industry are described as follows.

1. TinkerCAD: TinkerCAD is a free on-line 3D modeling software package that allows users to build models by drag and drop parts. It takes 2D files as the input and can generate 3D files accordingly. Therefore, it is very suitable for beginners. The TinkerCAD interface allows its users to freely adjust, save, and share on-line 3D files. It can also generate 3D files directly in the .STL format for 3D printing.
2. 123D Design: As compared to TinkerCAD, the 123D Design software is more advanced and intuitive. A beginner can easily start from scratch to build a model. A great amount of basic models are already stored in the software so that any user can edit the basic models and generate resulting 3D files in the .STL format.
3. SketchUp: It features a free and easy-to-use interface, which contains design tools and plug-ins for its user to create complicated 3D objects. This modeling system is composed of only lines and curves and this makes it suitable for architecture and engineering industry. However, this software doesn't allow the direct output in .STL format but an additional .STL output module is required to be installed.
4. FreeCAD: FreeCAD is a fully open source parametric engineering CAD software package. It is very suitable for the design of basic parts. Parametric modeling allows users to adjust parameters instead of meshes. The target users include engineers and product designers who need a professional way of modeling. This open source software runs on Windows, Mac, and Linux operating systems.
5. Rhinoceros (Rhino3D): This is a 3D modeling software based on non-uniform rational b-splines (NURBS). It has been very popular due to its functions and the diversity of its applications. It is easy to learn and it takes a wide variety of document formats. It is often used by industrial designers, architects, jewel designers, and artists to carry out rapid prototyping.
6. Solidworks: It is generally accepted as the mainstream 3D design software for commercial products and mechanical engineering. In addition to 3D modeling, SolidWorks also provides a variety of simulation, kinetics, design verification tools, and the reverse engineering capability. Solidworks is a powerful software package which is suitable for industrial components/parts design.
7. Cinema 4D: It is a general-purpose 3D modeling software package which is most used in designs, animations, and rendering applications. The highlight of this software is on 3D graphics and 3D model fabrication. The Maxon computation software includes several design options such as procedural/polygonal modeling, animations, lighting, textures, and rendering.

8. Autodesk 3D: It is mostly used in architectural, civilian, and mechanical engineering and has been a well-established CAD software for modeling since 1982. It is widely used in 2D drawings, architectural drawings, computer chipset designs, and basic 3D designs. It is one of the favourite drawing tools for designers and makers around the world. It features a 3DPRINT program that allows its users to directly send 3D models to 3D printing service providers.
9. Maya: It features an intuitive design interface that is suitable for creating characters, roles, and geographic scenes. It is one of the favorable 3D modeling tools among designers. The main applications include 3D animations and visual designs since it allows its user to change the proxy mesh based on the original mesh.
10. ZBrush: ZBrush is a new emerging modeling software package, which is suitable for creating different role types of characters. The appearance of ZBrush indicates a revolution of 3D modeling. This 3D printing software integrates 3D and 2.5D modeling with textures and painting. It allows a designer to create 3D models with amazing details such as different styles, textures, convex and concave features, and materials.

Slicer Software. In addition to a good printing tool, slicer software plays a very important role in 3D printing for a finished product with good printing quality. The configuration of parameters including the fill density, base, and support structure and a designer's own experience are the factors that are critical to the printing quality and the yield rate. A 3D model needs to be saved in the format of .STL or .OBJ files so that the model can be further sliced into layers by the slicer software. The instructions and parameters of the printing process are saved as G-code files so that a 3D printer can decode and carry out the printing process. There are more than a dozen open source slicer software packages available at the moment. Four of them are commonly used in the industry. They include three free software packages such as Cura, Kisslicer, and Slic3r and the paid version of Simplify3D. The features of these software packages are described as follows for the reference of a designer to choose the one that fits his/her requirements the best.

1. Cura: It is developed by Ultimaker and is one of the most commonly used software packages on open source 3D printers. It performs very fast at the slicer analysis and the printing and slicing functions can be used at the same time. Its main advantage is its interface which is very easy to learn. It is suitable for the beginners in the 3D printing territory. It also takes.jpg files as the input to print photos out.
2. Slic3r: It is the most popular slicer software for 3D printing on the market. Its main function is to carry out the slicer analysis of the .STL model files and convert the data into 3D printing instruction codes (G-Code). It is especially suitable for round objects with a shell such as a spiral vase.
3. Simply3D: It is gradually gaining popularity since it provides powerful functions for the slicer process. It features the most adjustable parameters and it has the highest yield rate and the best printing effect for delicate parts. It can be connected using a USB cable and it costs at only USD 150.

4. Kisslicer: This slicer software can print the most delicate surfaces. The surface of the finished part is the most delicate. However, the user interface is more complicated and it is more difficult to use for a beginner.

3 Evaluation and Analysis of the Features and Applications of 3D Model Platforms

3D model platforms form a critical part of the supply chain of the 3D printing industry. During the earlier stage of its development, it provided original equipment manufacturer (OEM) printing services such as making prototypes for customers. Nowadays, 3D model platforms provide a variety of diversified 3D model files for users to download. In addition, these platforms also allow professional users to upload their design works to the platform in order to facilitate the development of the 3D printing industry. There are more than ten 3D model platforms with a high level of user activities. The studies by vMaker (2015) [9] and Yusuf (2018) [10] proposed some good 3D model platforms. The platforms that are recommended by several makers based on their own experiences are also included in the investigation in this study. A total of seven 3D model platforms are analyzed and as follows.

1. Thingiverse: This platform is supported by the 3D printer manufacturer MakerBot. It is the largest platform in the world and has been operating for the longest time. It is the best introductory platform for beginners with a diversified collection of different types of model files. Its main collection includes household applications, action figures and toys, and engineering parts. Its interface is easy to use and it provides a search bar for a quick search in addition to the existing classifications. It also allows a user to preview the results. More than 1 million 3D models are collected in this platform and the total number of downloads exceeds 200,000,000. They often organize featured contests to encourage more people to exploit the potential of 3D printers.
2. MyMiniFactory: The total number of their files is less than the others. However, there are less duplicated objects and the yield rate and quality of model files are higher since their model files are always examined before being uploaded to the platform. The interface is available in six languages. Among all categories, the Scan the World category is the popular one since it features the 3D files of renowned artworks from various museums around the globe such as the Michelangelo's David at the British Museum and the Venus de Milo at the Louvre Museum.
3. Yobi3D: Yobi3D is a website that is developed by a Taiwanese design team. It features a search engine which operates in a way similar to Google for 3D model files. It collects more than 1 million 3D models. A quick search for models is available by keywords. Real-time previews are also available on-line so that a user can carry out the analysis of printing difficulty in order to determine the printer model that is suitable for a specific model file. Moreover, this platform also allows a user to configure the definition of his/her own printer in order to reduce the failure rate. The available model types include common action figures, engineering parts, home utilities, flowers and plants, and animals. It supports multiple languages.

4. Pinshape: This platform is supported by the Canadian 3D printer manufacturer Formlabs. The models that are collected on this platform are very delicate. It allows its users to determine whether to pay for a file that is downloaded. However, 90% of their files are free to download. It features the support of streaming by 3DPrinterOS. A user can edit, slice, and print any of their files on-line without downloading the file. It not only allows a designer to share his/her designs, but also can protect the original files. It also offers on-line custom services to designers at a price.
5. CGTrader: This platform is created by the 3D modeling vendor Marius Kalytis. The original target customers include 3D animations and the gaming market until it started to provide its users with the service of downloading 3D models recently. CGTrader features textures for most of its 3D models and therefore only 3D color printers can support this feature. It allows designers to upload their own files and profit from selling these files. A higher price tag is set for a model that is more delicate. The models can also be used for 3D animations. The platform also has a section specific for free files. By the end of June 2017, a total of 500,000 model files are collected and the total number of registered users reached 1 million.
6. Cults: This platform is the largest 3D model platform in France. It supplies 3D printing models of high quality for both free and paid downloads. A user needs to register a user account before he/she can download files. The 3D models that are collected on this platform are mostly provided by professional designers. A user is allowed to designate a designer to create designs for him/her. This platform has 40,000 model files which are provided by 8000 designers. A reminder on the website notifies its users not to sell the model files to other websites.
7. YouMagine: This platform is supported by 3D equipment vendor Ultimaker. The models that are collected on this platform are full of textures and many professional model files are already with colors. Therefore, the model files are more suitable for advanced users. YouMagine is different from others that it is devoted to protecting its 3D designers. In 2015, it announced 3DPL which permits the open source code that is specifically to 3D printing target users.

3.1 Descriptions of Dimensions for Analysis

The observation in this study indicated that the above-mentioned 3D model platforms offer a wide variety of model files even though they might just operate for a relatively short period. Each of these platforms has its own distinguishing features. The analysis in this study includes 4 primary dimensions which are respectively the website description, model file information, website function, and social interaction. The dimensions can be further classified into 22 items for analysis as shown in Table 1. These 22 items provide a helpful way to determine the application features of each 3D model platform.

Table 1. Dimensions for the analysis of 3D model platforms

Website description	Model information	Website function	Social interaction
Organization	Description of model file	Browsing function	Collection function
Date of issue	Model quality	Search function	Download counts
Country	Photo of finished part	Membership	User feedbacks
Model attributes	3D preview	Membership fee	Ways of sharing
APP support or not	Download format	Language	
	Descriptions of printer settings	Tag functions	
	Creative Commons		

According to the items in Table 1, a total of 10 makers who frequently use 3D model platforms are invited for the investigation. From the communities that are maker-relevant, the discussion threads on the above-mentioned 3D model platforms are available and can serve as a good reference for the analysis of these 3D model platforms. The results of the analysis are summarized in Table 2 as follows.

4 Discussions

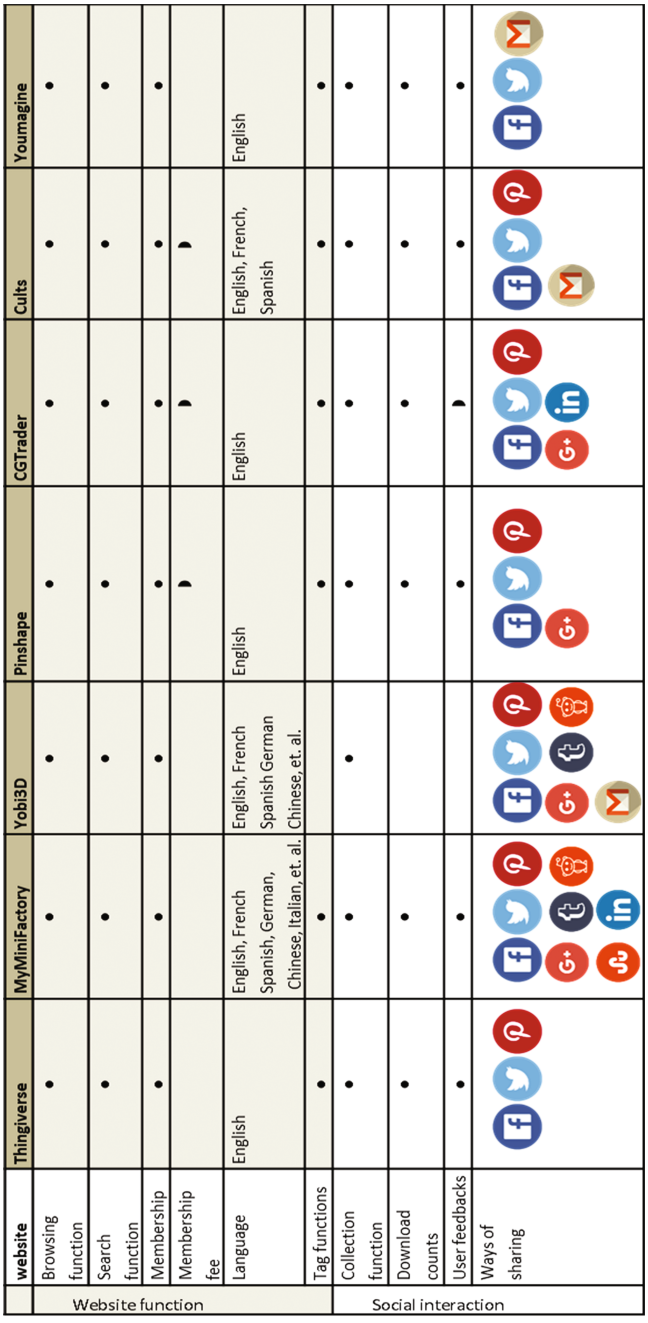
Based on Table 2, the discussions on these 3D model platforms are as follows.

1. 3D model platforms emerged since the past decade and developed rapidly for the last five years. Most of the 3D platforms are built up and supported by hardware/equipment manufacturers. The intention is to twofold. First, the platforms can assist users in printing their 3D artworks. Second, 3D printer lovers are gathered on the platform so that enterprises are able to interact with their users. Among these platforms, Cults was built up with the assistance from the government. Various 3D equipment vendors and governmental agencies also allocated resources in 3D model platforms and services. It is clear that the biggest source of revenue no longer comes from the equipment or consumables but from the database of 3D model files [3]. These platforms also created a more direct and closer relationship with users.
2. Although there is a wide variety of models that are collected on these platforms, a majority of these files are action figures, household applications, and engineering parts, followed by ornamental accessories, animals and plants, and educational models. Cultural models or artworks are still of minority.
3. At the moment, only Thingiverse and MyMiniFactory provide their support to apps. A user can use their apps to browse through and search for models and interact with other users. However, none of the apps allows its users to download models (Table 3).

Table 2. Analysis of 3D model platforms (1/2)

	website	Thingiverse	MyMiniFactory	Yobi3D	Pinshape	CGTrader	Cults	Youmagine
Website description	Organization	MakerBot	MyMiniFactory	n/a	Formlabs	CGTrader	Cults3D, France Post	Ultimaker
	year	2008	2013	2014	2013	2011	2013(FB)	
	Country	USA	Britain	Taiwan	USA, Canada	Lithuania	France	Netherlands
	Attributes	Household applications, Figurine and toy, Engineering parts, Accessories, 3D printer parts et. al.	Household applications, Figurine and toy, Engineering parts, Accessories, Museum collections Assistive products et. al.	Household applications, Figurine and toy, Engineering parts, Plant and animals et. al.	Household applications, Figurine and toy, Engineering parts, et. al.	Household applications, Figurine and toy, Engineering parts, Plant and animals Food medicine et. al.	Household applications, Figurine and toy, Engineering parts, Accessories, Plant and animals et. al.	Household applications, Figurine and toy, Engineering parts, Food et. al.
	APP support	•	•					
Model information	Description	•	•	•	•	•	•	•
	Quality	Good	Excellent	Good	Good	Good	Excellent	Good
	Photo of work	•	•		•	•	•	•
	3D preview	•	•	•			•	•
	Download format	.stl,obj , .es .xml	.stl obj	.obj, .stl, .fbx, .max .3ds,.ma, .mb, .blen, .3dm, .da, . dwg .dxf, .lwo, .ply, .skp	.stl, .ob, .zip	.obj .stl, .fbx .max, .3ds, .skp	.stl	.stl
	Descriptions of settings	•	•			•		
	Creative Commons			Not marked		Not marked		

Table 3. Analysis of 3D model platforms (2/2)



	website	Thingiverse	MyMiniFactory	Yobi3D	Pinshape	CGTrader	Cults	Youmagine
Website function	Browsing function	•	•	•	•	•	•	•
	Search function	•	•	•	•	•	•	•
	Membership	•	•	•	•	•	•	•
	Membership fee				◗	◗	◗	
	Language	English	English, French Spanish, German, Chinese, Italian, et. al.	English, French Spanish German Chinese, et. al.	English	English	English, French, Spanish	English
	Tag functions	•	•		•	•	•	•
Social interaction	Collection function	•	•	•	•	•	•	•
	Download counts	•	•		•	•	•	•
	User feedbacks	•	•		•	◗	•	•
	Ways of sharing							

4. From the aspect of model file information, all of these platforms provide descriptions of their model files so that a user can understand what the model is, what it is for, and what does it feature. The models from MyMiniFactory and Cults have better printing quality. Most of these platforms provide photos of finished parts after being printing out. The Yobi3D platform doesn't provide such photos since it operates as a search engine with a collection of 3D model files. From the aspect of 3D preview, Thingiverse, MyMiniFactory, Yobi3D, Cults, and Youmagine allow their users to view a model in 360° by dragging the model with a mouse. For model downloads, the formats of .STL and .OBJ are the most common file types.
5. For printer settings, only Thingiverse, MyMiniFactory, and CGTrader provide their users with the information of printer settings. The information include the actual dimensions, available formats, suitable printing technology, time required for printing, number of surfaces, file size, and any plug-in used. From the aspect of copyrights, most of the platforms clearly marked the privilege of Creative Commons (CC) except for Yobi3D and CGTrader. Therefore, most of the users can understand the applicable range of a model file under the Creative Commons license.
6. For the functions that are available on their interfaces, common functions such as browsing and searching are available on these platform. Memberships are provided by these platforms although it is not required to register as a member in order to download files. The membership deals with the interactive functions such as storing a model file or sharing a model file with others.
7. These platforms offer free downloads of model files. Among them, Pinshape, CGTrader, and Cults allows their users to pay for upgraded versions of a model file of high quality. Except for Yobi3D as a search engine, all the other six platforms provide their users with a tag function so that an uploaded file is tagged with several keywords. This function makes users easier to find and classify a model file.
8. In addition to social interactions, these platforms also provide their users with the Collect function for all of their model files. After registering as a member, a user can collect their favorable model files. Except for Yobi3D, the other six platforms mark the download counts for each model file. It is easier for a user to know how popular a model file is. On the other hand, the platform administrator can plan further cooperation with potential designers with a higher level of popularity. From the aspect of user feedback, except for Yobi3D, the other five platforms including Thingiverse, MyMiniFactory, Pinshape, Cults, and Youmagine allow their users to give feedback to their model files. Users are also allowed to upload photos of the printed part of a model part so that other users have a better idea of how the model file looks like after being printed. However, CGTrader users can only provide their feedbacks in texts since it doesn't allow its users to upload photos as their feedbacks.
9. Providing different ways of sharing a model file means a lot to a designer to make his/her model file public. Each of these platforms provides 3–8 different ways of sharing a file including Facebook, Twitter, Pinterest, Google+, Tumblr, Reddit, Stumbleupon, Linkedin, and Email. It is a faster way for a user to share his/her model files to others and this function also greatly enhance the visibility of a model file.

5 Conclusions and Challenges

With the advance in 3D printer technology, 3D printers are more affordable and popularized. There have been numerous studies of 3D printing technology, hardware/equipment, and materials. With the trend of crowdsourcing, open source and sharing, it is obvious that one of the critical parts of the future 3D industry lies in the 3D model platforms. However, few studies have carried out extensive investigation and comparison of 3D model platforms. In this study, seven 3D model platforms that are commonly used by maker communities are reviewed and analyzed from four dimensions which include website description, model file information, website function, and social interaction. It is known from the analysis that, Thingiverse and MyMiniFactory are the top two 3D model platforms that perform better on these four dimensions. A 3D modeling beginner is advised to use Thingiverse as the first step of his/her exploration. For advanced users or other users within special territories such as arts or assistive devices, MyMiniFactory should be able to meet their requirements. A designer can build his/her own brand by uploading models. After that, he/she can charge his/her customers for custom services such as 3D design, modeling, and printing. In general, the above-mentioned 3D model platforms have provided sufficient functions. However, they still need to overcome the challenges ahead as follows.

1. Insufficient format information of the file for download: Most of the current 3D model platforms provide files in .STL format for download. This file format is simple and it is easy for output so that it can be applied to virtually all 3D printers. However, the .STL format handles only the profile of a model without any information of color, material, or texture. Therefore, the printed parts have no color, texture, or detailed features. In an effort to enhance the printing technology, the American Society for Testing and Materials (ASTM) has been promoting new file formats including AMF and 3MF as the future download formats in an attempt to resolve the printed parts' problems of color, material, and texture.
2. Unclear intellectual property (IP) licensing status of model files: Most of the model files that are available on these 3D model platforms are licensed under the Creative Commons. This approach can acknowledge users of the file's licensing status when they download a model file for use. However, these platforms lack a mechanism of examining whether a model file that is uploaded by one user might infringe the other's copyright. In the future, 3D model platforms need to stipulate their regulation on examining any copyright infringement issue of the model files being uploaded.
3. Security vulnerability of file information: All of the platform administrators are encouraging their users to upload model files. However, they do not monitor or control the quality of the files being uploaded. They cannot guarantee the security of a model file which might contain a virus. This poses a potential risk to the platform itself and the security of user information. Therefore, these platforms are advised to implement risk management on their model files. In order to guarantee information security, a file is required to pass the secure authentication mechanism before it can be uploaded to the platform.

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