Adoption and Expansion of a 3D Printer Selection Engine

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Expansion and Dissemination of a 3D Printer Selection Engine

Abstract

Many big 3D printer manufacturing companies provide their printer specifications in disparate format making an “apples to apples” comparisons difficult. The purpose of the 3D printer selection engine is to display printer specification in a common format so users are able to make appropriate comparisons. It is anticipated the 3D printer selection engine, which is a first of its kind, can help the world’s growing maker movement select appropriate 3D printers. This paper focuses on the expansion and dissemination of a previously conceived 3D Printer selection engine. Technologies and tools used for the deployment of the web based selection engine are covered in the paper. The 3D printer selection engine previously designed, along with the website interface has been hosted on the university webpage. Student feedback on the usability and design of the webpage has been assessed and is reported in this paper. Assessment results indicated that the 3D printer selection engine is a novel idea and a useful tool and has been well designed. The results also suggest that making the site more visually appealing, including help buttons, and providing explanations and definitions of words and materials can improve the 3D printer selection engine.

Introduction

3D printing has been considered by many as the next technological and industrial revolution. Market availability of 3D printers has gone from few machines a decade ago to many hundreds recently. This trend has led to a huge momentum in maker culture across the globe as several users of products have now become makers of products. Rayna and Striukova have reported that “direct manufacturing (which corresponds to manufacturing end-use products with 3D printers) and home fabrication (on personal 3D printers) were found to be potentially significantly more disruptive, as they are likely to considerably increase value creation”. Laplume, Petersen, and Pearce have remarked that “industries diffusion of 3D printing technologies may change the role of multinational enterprises as coordinators of Global Value Chains (GVCs) by inducing the engagement of a wider variety of firms, even households”.

As 3D printing technologies continues to transform the industry and the maker movement with the user base of 3D printers continuously growing in the world aided by direct manufacturing and home fabrication, several companies are trying to compete in the 3D printer marketspace. Consequently, users are faced with many choices and hence rely on the printer specifications published on companies’ webpages and other literature to select a printer they need. However, 3D printer manufacturing companies provide their printer specifications in disparate format making an “apples to apples” comparisons difficult. Moreover, the information presented may be easy to decipher and compare for a person experienced in 3D printing technologies but may be difficult for a lay user. Many authors and experts have worked on 3D printer decision systems. These 3D printer decision systems were either based on matrix of 3D printers and their specifications, graph theory, or rule based expert systems to name a few. The goal of the all the previous research was to provide users with metrics and decision systems to make appropriate 3D printer choices based on their need. However, the previous research was intended for 3D printer experts or users who were extensively familiar with the 3D printing
technology and focused on few 3D printers. Moreover, some previous research either focused on revenue/pricing models or some focused exclusively on 3D printer accuracies and build volume. As there were few 3D printers on the market, the academic community did not see a need to come up with 3D printer selection/decision systems that covered the many categories of users and many 3D printers and a system that could be used “anywhere-anyplace”. In last few years many 3D printers have been introduced. Therefore user needs and the growing maker culture has further increased the usage of 3D printers. The usage of 3D printers has not only increased among technologically inclined users but also from lay users who want to learn more about 3D printers.

Agarwala and Chin developed a 3D printer selection engine that can be accessed by any user globally and making it a true “anywhere-anyplace” model. To the best of their knowledge, this tool and technology is first of its kind introduced ever in the marketplace. The authors have previously reported the system model, codes, and technologies that were used to design the selection engine. Links are provided to access resources such as selection engine, user feedback and to educate novice users about 3D printers and materials. The 3D printer selection engine model is like a digital index enabling any category of end user to match their product specification to 3D printers by means of a webpage mapped to a central 3D printer database. Any users connected to a network can enter the CAD geometry and product specifications into a web based form to enable selection of a 3D printer. It is anticipated that users can save time by using the 3D printer selection engine instead of visiting the hundreds of 3D printer manufacturers’ webpages available to match their design requirements with an appropriate 3D printer.

In this paper, the authors report the hosting of website interface on the domain of the authors’ university and the assessment of student feedback on the usability and design associated with the selection engine. Webpage design and usability feedback assessment is used for improving the engine. Background on the previous work is covered in the next section followed by explanation of the expansion and additional technologies deployed for the web based 3D printer selection engine. Evaluation instrument and assessment results are covered next followed by conclusions, acknowledgements and references.

Background

Figure 1 depicts the high level model for the system. “Level 1 of the system is used by a user to enter user category and desired product specifications and submit them to the 3D printer server. System Level 2 converts the users’ inputs into matching and mapping query to the database of 3D printers. Once a suitable match has been found, a webpage containing suitable 3D printers will be displayed in Level 3 with a hyperlink to the machine webpage hosted on the manufacturer’s website”.

The web based 3D printer selection engine was based on users selecting product and design specifications such as model dimensions, material type and the category of users to name a few. Figure 2 depicts the user interface as being developed localhost (author’s computer only). The 3D printer selection engine is now housed on a university server, has been expanded, and the webpage has been evaluated.
Figure 1. 3D printer selection engine Model

Figure 2. User and Server Interface on localhost (author’s computer only)
Expansion of 3D Printer Selection Engine

The authors have compiled the Active Server Pages (ASP)/ASP.NET web pages and the source codes into a web folder and hosted on the university webpage as a subdomain via worldwide web 2.0 (www2). The subdomain format www2 is used by servers for load balancing. The ASP/ASP.NET designs and their contents have been depicted in previous work \(^1\), \(^2\). The previous engine was hosted locally on a private computer. The current content is housed on a university server.

Figure 3. Communication tiers of the 3D printer selection engine. Courtesy Microsoft Corporation \(^{13}\)

The first layer is the web interface and the front end where the user enters the selection parameter and submits the selection form. As per \(^{3}\), The front end data (Tier 1) is transferred to the web server or the presentation tier (Tier 1) based on the codes and rules defined in the ASP and ASP.NET pages and the transfer process takes place using http (Hypertext transfer protocol or Internet protocol) as shown in Figures 3 and 4. A load balancer typically channels multiple submissions at once. ASP and ASP.NET pages are further parsed using an application server.
such as Microsoft’s Internet Information Services (IIS) server that makes connection with the database using a data layer of the application server. All of these are contained in Tier 2 of the application. The last Tier or Tier 3 is the database server which hosts the database in a secured format and communicates with Tier 1 and Tier 2 to add or retrieve data from the database.

**Dissemination of 3D Printer Selection Engine**

From the perspective of the selection engine, Tier 1 is the user interface that is presented to the user and is hosted as http://www2.ecu.edu/3DPrinterSelectionEngine/. 3DPrinterSelectionEngine is the web folder that contains all the ASP and ASP.NET webpages that contains rules and codes to interact with the user and make connections with the database.

![Image of Tier 1-User Interface of the 3D printer selection engine -Introduction](image)

**Figure 5. Tier 1-User Interface of the 3D printer selection engine -Introduction**

Figures 5 and 6 depicts the user interface of the 3D printer selection engine hosted on the university webpage as a subdomain webpage via worldwide web 2.0 (www2).
Figure 6. Tier 1-User Interface of the 3D printer selection engine-Selection Form

Figure 7. Tier 2-Data Source and Data Layer
Figure 7 depicts the web.config files and the source codes that are vital for mapping the ASP and ASP.NET pages with the database server that hosts the database. Figure 8 depicts the Sequential Query Language (SQL) server being hosted on the database server that forms a secure connection between the webserver, application server, and the database server.

Figure 8. Tier 3-Database (SQL) Server hosting the 3D printer selection engine database

Once the user enters the desired product specifications and submits them to the 3D printer server, the SQL data source establishes a connection between the selection form and the 3D printer Database. The 3D printer result and display webpage displays the results based on the user parameters as shown in Figure 9.
Assessment and Evaluation 3D Printer Selection Engine

An evaluation instrument was developed for assessing the web based 3D printer selection engine (see Appendix A for the instrument). The purpose of the instrument was to evaluate and improve the overall design and usability of the engine. The survey instrument categorized the prospective users of the engine and the survey participants as either being affiliated with the university or being external participants. Those affiliated with the university were further categorized into students, faculty, staff, alumnus, advisory board members or others. For those not affiliated with the university, the participants were categorized into high school/college students, high school/college faculty, Industry professional, or others.

At the beginning of the survey, the participants were asked to describe themselves as types of users with respect to 3D printers; i.e. beginner, designer, professional, or medical/dental. The next survey question inquired about the historic level of interaction of the participants with 3D printers as being either 1-2 times, 3-5 times, 6-10 times, or more than 10 times. The goal of the instrument was to gauge if there was any relationship between the type of users and their historic level of interaction with 3D printers.
The purpose of the subsequent questions was to gauge the overall usefulness and design for the 3D printer selection engine. The participants were asked to gauge the usefulness of the engine that ranged from not useful to very useful. The overall design of the 3D printer selection engine was evaluated from a scale that represented “not designed well” to “very well designed”. Following the questions related to design and usefulness of the engine, the participants were asked to respond to how well they were able to interact with the engine ranging from very difficult to easily.

The next questions covered the selection parameters listed on the selection form. The participants were asked to indicate how well the selection parameters were represented ranging from being inadequate to over represented. The next question polled the participants as to how well the 3D printing material selection list in the engine was covered ranging from “not well listed” to very well listed. The last question dealt with the results of the engine after the users submitted the selection form as ranging from results “not well displayed” to “very well displayed”. The participants were also requested for suggestions to improve the selection engine.

The intent of the first two questions was to relate types of users with respect to 3D printers; i.e. beginner, designer, professional, or medical/dental to their historic level of interaction with 3D printers. The authors attempted to gauge the basis on which the users classified themselves or if the historic level of usage of 3D printers had any bearing on the type of user. Due to the sample size, the survey results of student participants have only been analyzed and reported here.

![Figure 10: Type of Users and their level of interaction with 3D printers](image)

Figure 10. Type of Users and their level of interaction with 3D printers

Figure 10 depicts the frequency of level of interaction of user types with respect to 3D printers. Out of the fifteen participants who classified themselves as beginners, twelve indicated that they have interacted with 3D printers 1-2 times, 2 indicated 3-5 times, and 1 indicated 6-10 times. Out of eleven participants who indicated that they are designers, two indicated that they have interacted with 3D printers 1-2 times, six indicated 3-5 times, one indicated 6-10 times, and two indicated more than ten times. There was one participant who was identified as professional user and indicated their interaction with 3D printers more than 10 times. There was no one who identified themselves as medical or dental user. The results was consistent with the expectations.
as many user who identified themselves as beginners and designers indicated low levels and medium levels of historic 3D printer interaction.

The survey polled the participants on various aspects of the 3D printer selection engine such as usefulness, design and ease of interaction. They survey also inquired on how well selection parameters and material selection list was represented and how well the results were displayed. Figure 11 depicts the survey results and the average rating of each survey question. Table 1 represents the quantitative mapping of survey questions on a scale rated from of 1 to 4.

![Figure 11. Average rating of the 3D printer selection engine](image)

<table>
<thead>
<tr>
<th>Survey Questions</th>
<th>Rating Scales</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>3DP-Useful:</strong> How useful did you find the 3D printer selection engine?</td>
<td>Very Useful-4, Useful-3, Somewhat Useful-2, Not Useful-1</td>
</tr>
<tr>
<td><strong>3DP-Design:</strong> How well is the 3D printer selection engine webpage designed?</td>
<td>Very Well Designed-4, Well Designed-3, Needs Improvement-2, Not Well Designed-1</td>
</tr>
<tr>
<td><strong>3DP-Interaction:</strong> How well where you able to interact with the Engine?</td>
<td>Easily-4, Easy-3, Difficult-2, Very Difficult-1</td>
</tr>
<tr>
<td><strong>3DP-Parameters:</strong> How well are the 3D printing selection parameters represented?</td>
<td>Over Represented-4, Very Well Represented-3, Well Represented-2, Inadequate-1</td>
</tr>
<tr>
<td><strong>3DP-Materials:</strong> How well are 3D printing materials listed in the selection engine form?</td>
<td>Very Well Listed-4, Well Listed-3, More Materials Needed-2, Not Well Listed-1</td>
</tr>
<tr>
<td><strong>3DP-Results:</strong> How well are the 3D printer selection results displayed?</td>
<td>Very Well Displayed-4, Well Displayed-3, Needs Improvement-2, Not Well Displayed-1</td>
</tr>
</tbody>
</table>

Table 1. Quantitative mapping of survey questions on a scale rated from of 1 to 4
The average rating for ease of interactions, listing of materials, and display of results was more than three whereas the average scores for the usefulness, design, and representation of parameters was three or less. The average ratings were also analyzed based on the type of user. Figure 12 depicts the average rating of each category of user. The average rating of all was three or more than three for all user types except representation of parameters where the average of the ratings for all categories of users was less than two point five or less.

![Figure 12. Average rating of the 3D printer selection engine based on user](image)

The participants were requested for suggestions to improve the selection engine. The following list the participant comments.

- I do not think the selection engine needs to be improved.
- The machine can work.
- The engine was very useful and easy to use. I would suggest keeping it as updated as possible.
- Have definitions beside words like resolution so people know what increasing and decreasing the values do.
- No improvement needed.
- Improve on how the website looks is my only critique. It is a really cool idea!
- I couldn't see an 3D printer options after using the selection engine.
- Have a metric selection added.
- Add help tab next to section options
- Pictures did not show up on the tab second from the bottom.
- Give examples of what each type of material could be used for.
- It is well.
- It was a little hard to find the info/history of 3D printing for any beginners.
- Include description of what some parameters mean, i.e. "resolution", I was not sure what to put in those boxes and that altered the outcome.
- Indicate how many results were found and if none are found, indicate that.
• The content was exceptional but the website needs improvement to make it look more professional, giving it credibility.
• It seems very dry

It is evident from the results that the 3D printer selection engine needs improvement as far as representation and explanation of the selection parameters are concerned. From the comments, it would be beneficial to make the site more visually appealing and include help buttons following the selection options. It would also be beneficial to provide explanations and definitions of words and materials that might not be obvious to a beginner using the selection engine.

Conclusions

This paper focused on the technologies and tools used for the deployment and expansion of the web based 3D printer selection engine. The authors reported the hosting of website interface on the webpage of the authors’ university and assessment of student feedback on the usability and design of the webpage. Webpage design and usability feedback assessment was used to identify areas of improvement that are being worked on and the database is being expanded.

The purpose of the 3D printer selection engine is to display printer specification in a common format so users are able to make appropriate comparisons. To the best of our knowledge, this tool is first of its kind in the world. It is hoped that this engine can help the growing maker movement in the world by aiding users in helping them select appropriate 3D printers leading to more direct manufacturing and home fabrication and hence continue to fuel this industrial revolution.

Acknowledgements

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References

# 3DPrinter Selection Engine Feedback Survey

The purpose of the selection engine is to match end user requirements to available 3D printers. Your opinion is critical to the success of this project and engine. Please open the 3D Printer selection engine webpage, test it, and provide us with your feedback by responding to the items that follow.

Your Name: ___________________________ (Optional)

If you are affiliated with ECU, what is your academic/professional status?
- [ ] ECU Student
- [ ] ECU Faculty
- [ ] ECU Staff
- [ ] ECU Alumnus
- [ ] Advisory Board Member
- [ ] Other: _______

If you are NOT affiliated with ECU, what is your academic/professional status?
- [ ] High School/College Student
- [ ] High School/College Faculty
- [ ] Industry Professional
- [ ] Other: _______

Webpage of the 3D Printer selection engine: [http://www2.ecu.edu/3DPrinterSelectionEngine/](http://www2.ecu.edu/3DPrinterSelectionEngine/)

## How would you describe yourself with respect to 3D printer usage?

- [ ] Beginner
- [ ] Professional
- [ ] Medical/Dental

## How many times have you interacted with a 3D printer?

- [ ] 1-2 times
- [ ] 3-5 times
- [ ] 6-10 times
- [ ] More than 10 times

## How useful did you find the 3D printer selection engine?

- [ ] Very Useful
- [ ] Useful
- [ ] Somewhat Useful
- [ ] Not Useful

## How well is the 3D printer selection engine webpage designed?

- [ ] Very Well Designed
- [ ] Well Designed
- [ ] Needs Improvements
- [ ] Not Designed Well

## How well are you able to interact with the Engine?

- [ ] Easily
- [ ] Easy
- [ ] Difficult
- [ ] Very Difficult

## How well are the 3D printing selection parameters represented?

- [ ] Over Represented
- [ ] Very Well Represented
- [ ] Well Represented
- [ ] Inadequate

## How well are 3D printing materials listed in the selection engine form?

- [ ] Very Well Listed
- [ ] Well Listed
- [ ] More materials needed
- [ ] Not well listed

## How well are the 3D printer selection results displayed?

- [ ] Very Well displayed
- [ ] Well displayed
- [ ] Needs Improvement
- [ ] Not well displayed

Indicate how we can improve the selection engine. In addition, please provide any comments to augment your responses provided above.