Three Dimensional Printing:

An introduction for information professionals

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***Abstract* - Advanced by some as the next great emerging technology to enjoy overwhelming market penetration, three dimensional (3D) printing could have significant information implications, notwithstanding limited coverage in the information science literature. This review of complementary material from other sources provides the introductory definitions, technical descriptions and indications of future developments relevant to information professionals.**

Keywords - 3D printing; three dimensional printing; additive fabrication; digital fabrication; rapid prototyping.

I. INTRODUCTION

Three dimensional (3D) printing has the potential to impact the transmission of information in ways similar to the influence of such earlier technologies as photocopying and telefacsimile. This review identifies sources of information on 3D printing, its technology, required software and applications. Although the subject initially may seem to be of particular interest to engineers, efforts have been made to identify resources relevant to exploring the implications of 3D printing technologies for those working in the information sciences: librarians, archivists, museum collection specialists, and managers of documentation centers and information services in the public and private sectors. Accordingly, the following presentation provides definitions, reports the results of a literature review, explains the technology, and outlines directions for future work.

II. 3D PRINTING DEFINED

All sources identified through a literature search on the subject of 3D printing shared the common characteristic of providing a definition. The fundamental idea varies little from one source to another. Most agree that 3D printing consists of downloading a blueprint or a special computer file to a printer capable of 'printing' sophisticated three-dimensional objects through an additive process that 'prints' layers of material [1]-[10].

Bradshaw et al. [3] distinguish three fundamental methods for fabricating objects: 1. cutting the object out of a block of material; 2. creating a mold and then filling it to create the object; or 3. adding shapes together in order to make an object. The technology of 3D printing falls into the latter category, in which objects with moving parts can be created, impossible using the two other methods alone [3] [9] [11]. There is however, considerable diversity in actual 3D printing production.

The different techniques have led to certain semantic disputes. Wiegler [10] quotes a few researchers who feel that the term should be reserved for the particular 3D printing technique created by Zcorp, the company credited with creating a cheaper 3D printing technique in which a nozzle similar to a 'glue gun' is used to print out objects. Others believe that the term '3D printing' should be used generically, to include all types of additive manufacturing, because it is easily understandable by the general public [10]. It is this latter connotation which will be adopted in this review, employing the term '3D printing' to encompass all techniques that lead to a three dimensional object being printed, including such variations as 'selective laser sintering' and 'fused deposition modeling', which will be explained later.

II. LITERATURE REVIEW

As summarized by Weinberg, “the line between a physical object and a digital description of a physical object may (...) begin to blur. With a 3D printer, having the bits is almost as good as having the atoms” [9]. Librarians and information professionals, well aware of the important contributions of other electronic technologies to the disintermediation of information, should be predisposed to understand the implications of 3D printing. To assess the prevalence of articles on 3D printing in the information science literature, a three phase search for relevant articles was conducted. The first phase consulted three information science databases: *Library and Information Science Abstracts*; *Library, Information Science and Technology Abstracts*; and *Library Literature & Information Science Full Text*. The search terms employed were '3D print*', 'three-dimens* print*', 'three dimens* print*' and 'tridimens*print*'. When search results proved disappointing, a more general literature search was conducted in a second phase of the literature review. This involved a greater variety of sources, including reports and conference proceedings, newspapers, industry publications,

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electronic media and online information, and articles in engineering databases. When identified, relevant references were subsequently accessed to obtain a more comprehensive picture of the subject. Supplementary synonyms for the term '3D printing' found in this broader literature were carefully noted so that the initial three information science databases could be interrogated again in a third phase of the literature review.

Results of the three literature searches reveal that most of the relevant material on 3D printing has been published within the last six years, including many sources less than two years old. As a technology, however, 3D printing has been around for some time, and commercial printers "have existed for years" [10] [12] [13]. Bradshaw et al. [3] confirm that the first patent was deposited in 1977. One reason for the recent nature of most of the literature is that prices for 3D printers have dropped sufficiently that individuals can now afford to purchase their own equipment [1] [4] [6] [13]. This has encouraged greater interest in the possibilities of the technology.

The various sources of information frequently approach 3D printing as a subject quite differently. Newspaper articles provide general overviews of the subject, the 'meta subjects' and related topics. While they describe printing techniques, they rarely employ scientific terms such as 'fused deposition modeling', for example. This can lead to confusion when the full range of 3D printing possibilities is not described. Reports provide more in-depth and accurate descriptions. Blogs generally post the most recent developments, but commercial blogs unsurprisingly tend to concentrate on what specific 3D printing companies have to offer. Manufacturing company websites tend to provide a considerable amount of information about 3D printing as a process, including detailed technical information. Those that print from files created by customers even provide links to web pages for non-commercial software. Unfortunately, meta subjects and related topics are rarely covered. Engineering articles range from a tight focus on elements of 3D printing as a process, such as improving the viscosity of material to be printed, to more general considerations of meta subjects. The *Rapid Prototyping Journal* is a particularly valuable source of engineering articles in this regard.

Given the information implications of the resources identified through the more general literature search, the initial search of information science databases was repeated to take into account the terms identified in the more general literature search. This search yielded only four additional results. Two of these articles [14] [15] were by the same author, giving a brief assessment of one commercial 3D printer and of a particular piece of modeling software. Another [16] discussed combining two databases to obtain a 3D printable file of the outline of buildings in Norway. The three articles were very focused on their specific topics, and none discussed the information implications of 3D printing.

Although also narrowly focused, the fourth article [17] does describe an application of 3D printing with information implications. It discusses the use of 3D scanners and a 3D printer to create replicas of wooden stamps. The article concludes by explaining that the stamps are now easier to share with other libraries and museums, an illustration of a potential contribution 3D printing might make to extending access while preserving original archival and museum materials.

Articles relevant to the information implications of 3D printing were also discovered in the more general search conducted in the second phase of the literature review. A kinematic library was identified which has made 3D printable files of kinetic models available online [18]. The metadata scheme developed for this library might have served as a good starting point for reflecting on the classification and cataloguing of 3D printable files, but unfortunately, it does not appear to be systematically maintained, and many of the supplied links are broken [19].

Two engineering articles also found in the same general literature search outlined attempts to create classification schemes for 3D printing. Ingole et al. [20] make relevant observations about the need for more formalized standards for 3D printing and discuss some of the difficulties associated with the proprietary standards associated with commercial machines. Certain components of the proposed classification scheme, such as the use of single digits to code subjects, would have benefited from input by information professionals. The second engineering article, by Mortara et al. [21] demonstrates an awareness of such important classification concepts as faceted classification, but the proposed classification scheme is clearly aimed at engineers, and would not be easy to use for publicly accessible repositories.

III. TECHNICAL OVERVIEW

This section explains technical aspects of 3D printing found in reviewed sources. The utility of 3D printing rests in its capacity to cheaply print complex objects, such as already linked up chain-mail, using a variety of materials [2]. Certain accounts concentrate exclusively on a single 3D printing application. Seulin's article [17] on wooden stamps is an example. While these resources explain the process involved in creating a 3D object, they often focus on a specific printing technique and on a specific 3D printer.

Areas of interest which have used 3D printing to create objects include aeronautics, architecture, automotive industries, art, dentistry, fashion, food, jewelry, medicine, pharmaceuticals, robotics and toys [2] [12] [22]. 3D printable files of physical models of educational concepts would also interest academic and school libraries. Knapp et al. [23] explain that commercial models "are expensive", and give the example of "an anatomical model of the heart" which can "cost up to $600." A 3D printer can be purchased for under $1,000 and materials for "even the largest model (...) would likely cost under $50" [23]. As noted previously,

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the preservation of artifacts is another potential use of 3D printing that would be of interest to information professionals [7] [23].

Both open-source and proprietary software may be used to acquire digital files of 3D objects during the data acquisition phase of production. Lipson and Kurman [6] credit "the emergence of cheaper, and increasingly accessible computer aided design software (CAD)" for the increasing interest in 3D printing. A number of authors mention the use of 3D scanning, which uses basic cameras and freely provided software, rather than commercial systems, to obtain digital data of existing objects [2] [9] [17] [22].

Authors also confirm that there is no agreement on file formats for 3D printing [6] [20]. The range in the types of files that currently exist include PLY files, ObjDF files, RP files, STL files VRML files and ZPR files [4] [14] [23]. Inacu et al. [23] believe that STL "is, and for the foreseeable future, will be the standard mode of data exchange in the Rapid Prototyping industry." Software used to create printable 3D files includes modeling software, file converters, model 'repair' software to clean-up files, and path generating software.

Help is also available online for anyone interested in creating printable 3D files. Google Sketchup [24], for example, does not require a user fee to access a basic level of service. Turning a model into a printable 3D file involves following instructions from a free tutorial provided by a for profit company called Shapeways [25].

Both Cornell University and the University of Bath have designed open-source 3D printers which are widely recognized for making all 3D printers more affordable: Fab@home and RepRap [7] [13]. To acquire one of these open-source 3D printers, interested parties obtain the basic building materials, follow construction instructions shared on Wikis, and then purchase printing supplies [7]. Bath even allows the commercial resale of its printers. Lipson and Kurman [6] note that Creative Commons initiatives have been inspired to work on open-source hardware licenses. Fab@home's ultimate objective is to build a machine capable of producing "complete, integrated, functional electromechanical devices" [7]. The goal for RepRap is to enable it to replicate itself by printing out all parts for a new RepRap [6].

The cost of a RepRap printer in 2010 was about $525, and it could replicate 50% of itself [13]. The operating cost of 3D printing materials can be less than $1 per cubic inch [23]. Caution must be exercised when quoting published costing information, however, since prices have been dropping so fast that they are quickly outdated. Wiegler [10] cites the example of a professor who bought a commercial 3D printer in 2005 for $31,000, noticed that the price had dropped to $19,000 in 2008, and speculated that it would drop to $10,000 by 2013.

Commercial Printers that use more advanced techniques to print objects are usually equipped with proprietary software [14]. Companies that sell 3D printers include 3D Systems, Objet Geometries, Solido LTD, Stratasys and Z Corp [2] [18]. Lipson and Kurman (2010) report that both Hewlett Packard and Xerox "are investing in 3D printing research and technology development" [6].

Several types of material can be used to print objects. Various printers handle a variety of materials, and some can even produce objects using more than one type of material. While the most commonly used materials are plastic, metals and ceramics, more exotic materials, such as chocolate, may also be used [6] [7].

There are two major variations in printing techniques. In one instance, material is deposited on a surface, and the depositing implement of the printer pulls up after a layer has been deposited in order to deposit the next layer [2]. Support material might be put in place to protect the structural integrity of the object, but must be removed later [15]. In another instance, a layer of powder or liquid is present on the printing surface. A binding technique is used to change parts of the powder or liquid in the first layer of the object. The printing surface is lowered, more powder or liquid is added, and the process is repeated to form the next layer [26]. The remaining material supports the weight of the object as it is built. Binding techniques include adding glue to material, adding an 'ink' that solidifies when exposed to ultra-violet light, or using a laser to bind material [2] [6].

Although different techniques have specific names, a semantic shift in the terms used to describe generic 3D printing has resulted in a number of variations. Selective laser sintering, fused deposition modeling and stereolithography are among the most often mentioned techniques [4] [20] [26] 27]. Stereolithography uses a liquid polymer bonded by a laser; laser sintering uses a powder which is also bound by a laser; while fused deposition modeling simply deposits material on a printing surface [28]-[30]. Certain techniques also require post-processing of the printed objects in order to solidify them or to improve their appearance [26] [31]. Post-processing steps can include 'bed manipulation', which entails forcing a change to all the material that will only have an effect on bonded parts, removing powder or support materials, heating the object, or dipping it into something else (infiltration) [26].

IV. CONCLUSION AND FUTURE WORK

Not all technical information about 3D printing could be shared in this introduction of the subject. Documenting the technology, very much a work-in-progress, must also recognize that not all authors agree on the likelihood of 3D printing gaining wider dissemination into the homes of individuals [10]. Also, as a still emerging technology, 3D printing is not without its problems, such as slow printing speeds [6]. Nevertheless, as prices are decreasing, the number of 3D printers sold worldwide has been growing steadily. And as market penetration increases, the information implications of 3D printing technologies will

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expand as well. These include legal considerations and parallels associated with the spread of desktop computers [6] [7] [9]. Published works related to the information economy [32] [33], the democratization of manufacturing [34], and on the concept of the 'long tail' [2] will also assume greater significance [6].

The lesson learned from this initial effort to introduce 3D printing to information professionals is that explanations of the technology will not, as yet, be found in their professional literature. Hopefully, however, as they begin to appreciate the potential of desktop 3D printing technology, information professionals will have more to contribute to a greater understanding of its implications.

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