Masaryk University
Faculty of Informatics

3D printing protocols

Bachelor's Thesis

Peter Benčík

Brno, Fall 2016

Masaryk University
Faculty of Informatics

3D printing protocols

Bachelor's Thesis

Peter Benčík

Brno, Fall 2016

Replace this page with a copy of the official signed thesis assignment and the copy of the Statement of an Author.

Declaration

Hereby I declare that this paper is my original authorial work, which I have worked out on my own. All sources, references, and literature used or excerpted during elaboration of this work are properly cited and listed in complete reference to the due source.

Peter Benčík

Advisor: John Smith

Abstract

Keywords

3D printing, additive manufacturing, …

Contents

List of Tables

List of Figures

1 Introduction

The traditional 2D printers have become an area of interest for a general public somewhere in 1980s. During this time of almost 40 years, the printing industry went from very diversified area, dominated by incompatible technologies and proprietary frameworks to the state where vast majority of devices "just work" regardless of the mix-and-match of manufacturers of a computer and a printing device. Around the year 2010, additive manufacturing devices (also knows as 3D printers) experienced an extreme rise of interest. Unlike 2D printing, dominated by few companies and a long tradition (enabling it to set up a relatively universal system), 3D world is cluttered with hundreds of companies making their own 3D printers, many of which are build on closed frameworks and proprietary protocols. Inspired by the evolution of a traditional printing, 3D printer manufacturers and big software corporations alike, are pursuing a goal of a near-complete compatibility. This paper will try to introduce the most known and perspective protocols and technologies pioneering a way in this area.

2 Internet printing protocol

Now considered an industry standard in network printing, Internet printing protocol, formerly developed by Internet Engineering Task Force Internet Printing Protocol work group (until the version 1.1), now developed under the PWG workgroup is an HTTP based printing protocol, which in it's latest version describes itself as a standard "that allows personal computers and mobile devices to find and print to networked and USB printers without using vendor-specific software[1]"

2.1 3D Support

The PWG has developed an extension for IPP enabling it to be used for 3D printing. The aim of the extension is to take advantage of the development journey of traditional 2D printing, making it as seamless experience as possible.[2] The first user-case in the draft of the extension, envisions the goal like this: "Jane is viewing a 3D object and wishes to print it. After initiating a print action, she selects a 3D printer on the network, specifies material and print settings, and submits the object for printing"[3]. The printing mechanics in the extentson is almost the same as in IPP for 2D printing [4], extending it's capabilities for a client devices to query an IPP 3D printer for it's abilities such as available materials, multiple material printing support, etc.. [5]. Required file format for IPP 3D is 3D Manufacturing File Format (3MF) (which is an XML based file format developed by 3MF Consortium) and PDF in versions 1.7 and 2.0 are recommended, internally taking advantage of U3D and PRC - both binary formats. IPP 3D focus on high level formats allowing for all the slicing to be happening on the printer itself, thus removing one step from traditional 3D printing workflow.[6]

---

1. https://www.pwg.org/ipp/everywhere.html
2. 3D Printing and the Practical Applications of Time Travel, https://www.pwg.org/3d/index.html
3. 3.1.1, http://ftp.pwg.org/pub/pwg/ipp/wd/wd-ipp3d10-20160824.pdf
4. 4.1, http://ftp.pwg.org/pub/pwg/ipp/wd/wd-ipp3d10-20160824.pdf
5. 8, http://ftp.pwg.org/pub/pwg/ipp/wd/wd-ipp3d10-20160824.pdf
6. 4.3, 4.4, http://ftp.pwg.org/pub/pwg/ipp/wd/wd-ipp3d10-20160824.pdf

In conjunction with support of services like LDAP and Bonjour, IPP 3D has a potential to 3D printing much more user friendly.

2.2 CUPS

CUPS (an abbreviation for former name: Common Unix Printing System) is the standards-based, open source printing system for UNIX-like computer operating systems[7]. Although originally using LPD, the IPP was later chosen as a base protocol, quickly becoming a default-choice for majority of linux distributions. CUPS was purchased by Apple Inc. in 2007[8]

2.2.1 3D support

Under the Apples leadership, the first version to support 3D Printing was CUPS version 2.1, release candidate 1.[9] This version only supported basic 3D printers with no built-in filters, based on PWG White Paper policy [10], thus including vast majority of open source printers, but leaving almost all printers built on closed frameworks behind.

7. https://www.cups.org
8. https://www.cups.org/blog/2007-07-11-cups-purchased-by-apple-inc..html
9. https://www.cups.org/blog/2015-07-31-cups-2.1rc1.html
10. http://ftp.pwg.org/pub/pwg/BOFs/3d-printing/wd-apple-ipp3d-20150413-rev.pdf

3 3D Printing in Windows

Since the announcement of Windows 8.1 Microsoft offers a native support for 3D printing in it's operating systems, pursuing goal noticeably similar to the PWG working group: "One of the goals for Windows 8.1 is to address these pain-points [exporting model several times during one print workflow, intermediate data formats, incompatibility issues, etc…] so that 3D printing can become more seamless and ubiquitous" and "Define a feature set for 3D printing that represents the capabilities of 3D printers that are on the market today or in development." [1]. The design decision in this effort was to extend the existing 2D printing pipeline with 3D capabilities, meaning that they both share the same driver mode, application interface and pipeline. This shift of paradigm means that the applications are decoupled from the device [2] thus extending the interoperability potential. Another important consequence is the support for plug and play feature, since Microsoft provides a generic driver generating standard G-code and providing a set of attributes that can be overridden by the device combined with Windows Update distribution of drivers. This way of implementation is not, however, dependent on a given protocol, rather the manufacturer of the device is required to package their protocol of choice into the driver together with the mesh repair, slicing and render filtering functionality, as this is (unlike the IPP 3D) all done on the driver side. The pipeline, also takes advantage of the 3MF format, encapsulating in into openXPS, where again, the driver is responsible for extracting the 3MF from openXPS package and translating it into a printer understood language.[3]

3.1 Support for the developers

Microsoft provides a separate SDK for the 3D printing functionality offering APIs for both, connecting to the printing pipeline form the point of a consumer application, and the driver development includ-

1. https://blogs.windows.com/windowsexperience/2013/08/22/3d-printing-support-in-windows-8-1-explained/
2. https://channel9.msdn.com/Events/Build/2014/2-534
3. https://channel9.msdn.com/Events/Build/2013/3-9027

ing the integration of plug and play feature as well. The library for conversion to 3MF format is also provided. One downside, worth of mention is that for use of plug-and-play feature a unique USB identifier is required, hence projects like RepRap will not take advantage of it as long as they are not registered companies, therefore not having a unique USB ID.[4]

3.2 Web Services on Devices for Printing

In the domain of Network printing, Microsoft offers it's own connection protocol called Web Services on Devices for Printing or WS-print. WS-print is a part of Web Services on Devices (WSD) which is a technology that "allows network-connected IP-based devices to advertise their functionality and offer these services to clients by using the Web Services protocol" and also "provides a network plug-and-play experience that is similar to installing a USB device" [5] by broadcasting itself to the network or being discoverable by Probe Message (WS-Discovery protocol). WS-print was introduced in Windows Vista and is currently available in four specifications: WS-print v1.0, v1.1, v1.2 and v2.0.[6][7] In the time of release of the native 3D support, the WS-print v1.2 was publicly distributed. In Windows 10, the protocol specification was upgraded to v2.0 including among other features also a capability of "a mobile client to print without the aid of a driver, and [it] can be used to enhance the capabilities of a v4 print driver." [8]. The protocol's functionality as stated in it's standard allows the user to "send a job along with detailed descriptive and processing information. Either user can be informed when the job has started printing and when it has finished printing. In addition, a user can cancel a previously submitted job, determine the status of the printer and its jobs, and determine the default and allowed values for elements required in print

4. https://msdn.microsoft.com/en-us/windows/hardware/drivers/3dprint/microsoft-standard-driver-for-3d-printers-
5. https://blogs.technet.microsoft.com/askperf/2008/02/11/ws2008-the-wsd-port-monitor/
6. https://msdn.microsoft.com/en-us/library/windows/hardware/dn641604(v=vs.85).aspx
7. https://msdn.microsoft.com/en-us/windows/hardware/drivers/print/ws-print-v1-1
8. https://msdn.microsoft.com/en-us/library/windows/hardware/dn641604(v=vs.85).aspx

job submission. " [9]. WS-print protocol also supports one-way/two-way control messaging and eventing. Microsoft provides WSDAPI that can be used for both client and server (device) implementation.[10]

3.3 3D Network printing through Microsoft IoT Core Operating System

Windows IoT Core is a version of Windows 10 operating system optimized for a small (possibly display-less) devices such as Raspberry Pi, also compatible with Microsoft's Universal Windows Platform API. As Microsoft demonstrated[11] the API includes a capability for a device running IoT Core to act as a wireless print server for 3D printers, thus making any printer which is compatible[12] with Windows 10 end-to-end 3D printing solution effectively wireless (Assuming that printing clients are part of Microsoft's 3D printing ecosystem.)

9. Chapter 6, v2.0 standard, http://go.microsoft.com/fwlink/p/?LinkId=534008
10. https://msdn.microsoft.com/en-us/library/aa825969(v=vs.85).aspx
11. https://developer.microsoft.com/en-us/windows/iot/Docs/3DPrintServer
12. https://developer.microsoft.com/en-us/windows/hardware/3d-print/printing-partners

4 Conclusion

Even though effortless 3D printing is still a long way ahead, the trend in the industry is impossible to overlook. It appears that with the support of companies like Auto-cad, Microsoft or HP, the 3MF consortium and it's 3D Manufacturing Format could very likely be the cornerstone of a new era in 3D printing industry. In conjunction with the efforts of PWG on driverless printing and Microsoft's end-to-end user experience, it's easy to believe McKinsey's prediction that the additive manufacturing industry will rise to $550 billion annually by 2025 [1].

1. The Economist. ISSN 0013-0613. Retrieved 2016-05-08.