Documenting Downloadable **Assistive Technologies**

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Erica Charbonneau

Abstract

Documenting Downloadable Assistive Technologies

This major research project explores *Downloadable Assistive Technologies* (DAT) and the possibilities as well as the limitations of publishing and fabricating DAT through online 3D printing communities. A design probe was used for this research within the context of *Thingiverse*, in the form of a 3D printed dog wheelchair design probe – the *FiGO Dog Wheelchair*. *FiGO* enabled an exploration of issues of design and communication of DAT. Through research involving both end users as well as a health professional, as well as interactions within the *FiGO* project page on *Thingiverse*, criteria for communicating DAT published on *Thingiverse* were developed, and a second *FiGO* project page reflecting these criteria was prototyped and evaluated. It is concluded that DAT could potentially benefit most greatly from a structured set of guidelines of use and communication of risks in the form of a design brief, and that there are specific considerations to developing a meaningful design brief for DAT including: 1) Tell the story of the design, 2) Do not make assumptions about the end user, 3) Clear instruction about the design use, 4) Inclusion of source files to enable user participation and extension of the design.

Keywords: 3D printing, co design, Open Design, Inclusive Design, digital fabrication, assistive technology, Thingiverse, pet wheelchair, Do-It-Yourself, Instructions, Downloadable Assistive Technologies

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Contents

List of Figures

List of Tables

Introduction

As digital fabrication is rising in popularity and becoming more accessible to consumers, people are participating more frequently in the practice of downloading, fabricating, and publishing 3D models or design blueprints online. There are no limits to the variations of objects that can be found and downloaded from various online 3D printing model repositories. *Thingiverse*, for example, has grown into a massive community since its launch in 2008. *Thingiverse* "reached a landmark one million uploads and 200 million downloads" on October 29 2015. [1] While the growth of participation is irrefutable, many questions arise from the practice of sharing, creating, downloading, and printing downloadable designs, including the questions of motivation, community, safety, disruption, and the design and availability of technologies that make digital fabrication possible.

Downloadable Assistive Technologies

Downloadable Assistive Technologies (hereafter DAT) is one area of growth in digital fabrication where many of these questions are starting to emerge, and is an area that the Thingiverse community is actively engaging in. In Fall 2015 *Makerbot* announced the *Assistive Technology Challenge*, where community members were encouraged to design assistive technologies to be printed by a *Makerbot*. [2]

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[1] *"Celebrating a Maker Milestone: 1 Million Uploads on MakerBot's Thingiverse (2015, October 29)."*

[2] *"Makerbot Assistive Technology Challenge."*

FiGO Pet Wheelchair, photo courtesy of Pete Thorne Photo

DAT are an interesting subject of research because issues of motivation, community, safety, and disruption [3] are recognizable in the challenge that DAT represent to the prevailing model of medicalized assistive devices. [4]

DAT refer to designs of assistive technologies uploaded online with the intention of being downloaded and fabricated by an end user. This activity is based on the concept of *Open Design* - the material or physical equivalent of *Open Source* software. [5] It suggests that physical designs that are freed from the barriers of strictly bound commercial designs benefit from the innovative potential of sharing source material. While users are often required to conform to standardized medical or assistive devices, 3D printing of DAT enables users to customize their devices for both functional and aesthetic reasons that can lead to a better outcome and fit for users needs. Hurst and Tobias explore in their paper this idea of customization and outcome and suggest, "empowering users to make their own Assistive Technology can improve the adoption process (and subsequently adoption rates) [of assistive technologies]". [6] Users can express themselves through individualized assistive technologies that are customized to be optimally functional for them as well as being aesthetically pleasing. However a number of

[3] Buehler, Erin, Branham, Stacy, Ali, Abdullah, Chang, Jeremy J., Hofmann, Megan Kelly, Hurst, Amy and Kane, Shaun K. *"Sharing is caring: Assistive technology designs on thingiverse."* pp. 525-534. ACM, 2015.

[4] Hayes, Jeanne, and Hannold, Elizabeth Lisa M. *"The road to empowerment: a historical perspective on the medicalization of disability."* Journal of health and human services administration (2007): 352-377.

[5] van Abel, Bas, Evers, Lucas, Troxler, Peter, and Klaassen, Roel. *"Open design now: why design cannot remain exclusive."* (2014).

[6] Hurst, Amy, and Tobias, Jasmine. *"Empowering individuals with do-it-yourself assistive technology."* pp. 11-18. ACM, 2011.

concerns arise. DAT may not be rigorously tested and approved by medical professionals – as is the case for traditional assistive devices. The potential for modification and innovation is clear, but there are risks taken on by end users in terms of potential adverse or neutral outcomes, and there may also be a certain resistance from the medical community, as they do not believe makers will perform the necessary thorough risk assessments that a health professional might provide. In a recent study looking at challenges associated with *Do-It-Yourself* (hereafter DIY) assistive technology in the context of children with disabilities, medical professionals who were participants in the study "questioned whether or not non-professionals would have the required engineering knowledge and experience to be able to take similar precautions [as they do in their practice]". [7] Designers of DAT play a role in this milieu, potentially managing trade-offs between articulating highly constrained (commercial) design and completely open (downloadable) design in order to produce safe (regulated) design while keeping the design open for innovation.

Problem Space

DAT are very difficult to manage and control as they give full agency to the user to fabricate, and potentially amend, the artifact. Given the lack of control the designer has over the design once it is published and free to be openly downloaded, the intent of the designer could be miscommunicated and the designer's vision and criteria not maintained. How do we communicate constraints and intent for this, especially for assistive and/or medical devices where there is risk for physical injury due to misuse of a DAT? This project is aimed to present methods for producing and documenting DAT to

[7] Hook, Jonathan, Verbaan, Sanne, Durrant, Abigail, Olivier, Patrick, and Wright, Peter. *"A study of the challenges related to DIY assistive technology in the context of children with disabilities."* pp. 597-606. ACM, 2014.

both facilitate the design process as well as to support novice makers in extending designs in a generative manner, all the while presenting methods to communicate potential risk and application for the design intended by the designer. Novice makers are chosen as the target group for this study as experts may not benefit as much from briefing on guidelines for use (material properties, fabrication techniques, etc.) and/or risk, while novice makers lack knowledge of both of these aspects. A designer is an expert at design application, but may not be familiar with health risks, a health professional is an expert in health risks, but may not be familiar with design application, and the novice maker (or end user) is an expert in their preferences, but may not be familiar with both design application and health risks.

In this Major Research Project, I explore issues of DAT design documentation through reflection on a DAT design probe. [8] A design probe is the use of an artifact to inspire new ideas in the design process. [9]The design probe took the form of a prototype DAT of the *FiGO Rear Support Pet Wheelchair*. The design probe enabled the exploration of themes relating to the *Open Design* context of assistive technology and digital fabrication, specifically focusing on how these DIY designs could be communicated to the end user. These themes are discussed and relating research questions and implications for design are explored.

My master's research began by exploring existing DAT on the *Thingiverse* platform, looking particularly at how they are communicated to end users via the project page. I then developed principles that could be used to brief novice makers on the risks and

[8] Mattelmäki, Tuuli. *"Design probes."* (2006).

[9] Jeng, Taysheng, Yu-Pin Ma, and Yang-Ting Shen. *"iAWN: designing smart artifacts for sustainable awareness."* Context Diversity, pp. 193-202. Springer Berlin Heidelberg, 2011.

applications associated with DAT, with the goal to empower them to fabricate and/or expand upon the design. I accomplished this through observation and discussion with two participants: one veterinary professional and one owner a dog in need of a wheelchair. I interacted with a veterinary professional to gain insight on associated health risks and engage with a dog owner in order to gain insight on how to communicate guidelines for use of the design. In parallel to this, I gathered data based on my interactions with commenters on the existing *FiGO Pet Wheelchair Thingiverse* page, by answering their questions and responding to their feedback on the design. I developed criteria for design briefing based on an analysis of the novice maker user experience in combination with expert knowledge of the field as well as the user interactions on *Thingiverse*. The design brief in this research paper refers to the project documentation of the design on *Thingiverse*, which is embedded in the project page of each Thing uploaded to the website. With these criteria I produced an updated *Thingiverse* page for *FiGO* that I then explored with both stakeholders. In doing so, I learned more about how non-designers interact with DAT, including some of the barriers non-designers face in this process.

Through the analysis of these research activities, I gained insight into what characteristics are essential to developing a meaningful design brief that could further empower people to both fabricate and remix DAT, while communicating the risks associated to fabricating these assistive technologies. I also gained insight into how designers can strike balance between highly constrained (commercial) design and completely open (downloadable) design.

Research Questions

1. **What are design briefing methods that could educate novice makers on risk and application when engaging in DAT?**

    a. How can these methods also benefit other stakeholders (health professionals and designers/adept makers)?

2. **What are the barriers to Downloadable Assistive Technologies for non-designers, even when provided a toolkit to operate from?**

Design Probe

FiGO, a DIY pet wheelchair (see Figure 1, pp.10), was chosen as a case study to explore DAT due to the nature of the current pet product sector. The pet product sector is not widely regulated and as such it is a sector where customized or personalized items are common and are often created without expert or regulatory oversight. There are fewer barriers to designing, fabricating, and testing products for pets, similar in many ways to the current human DAT sector. As noted by the American Pet Product Association, there are very few listed regulatory requirements for pet products other than for pet food or pesticide products, and products that are intended to be worn by pets, or to be used for exercise or pet housing, are not regulated. [10]

Prior to this MRP, two *FiGO* wheelchairs had been produced, and a new further improved version of the design was utilized as a design probe for this research process. The design probe *FiGO* is a 3D printable pet wheelchair kit that aims to disrupt the current market for assistive pet devices. Commercial wheelchairs for domestic animals are very expensive (non customized rear-support-only dog wheelchairs costing up to $525.00 USD) [11] and often inaccessible to many pet owners due to cost and availability of veterinarians and veterinary orthotists with pet wheelchair expertise. Issues of access arise for individuals who need a pet wheelchair for their animals at short notice due to a trauma related injury to the pet, when on a budget, at a remote location, or perhaps for temporary purposes

Figure 1. The first two iterations of the *FiGO Pet Wheelchair* (photo courtesy of Pete Thorne Photo)

during recovery from surgery. Embedded in the concept of *FiGO* is the empowerment of individuals to build their pet's wheelchair with a combination of reasonably available digital fabrication (3D printing) and easily available traditional making or small-scale construction. *FiGO* uses parametrically designed 3D printed joint pieces (see Figure 2, pp.11) that fit into acrylic or aluminum tubing, which can be easily customized to the dog for both functional and aesthetic purposes. All materials used in the kit that are not 3D printed can be sourced locally at most hardware stores.

The kit includes ten 3D printed customizable joint pieces in total that can be printed with a variety of consumer grade 3D printers in ABS or PLA plastic. The printer used for this iteration was a *Makerbot Replicator 2X*. Each piece takes roughly an hour to print, so the print time can be averaged to 10 hours. Other than the time commitment, the material cost is very low as long as the pet owner or fabricator has access to a 3D printer. Increasingly, public spaces such as libraries, schools, and makerspaces are providing publicly accessible 3D printing facilities and equipment, for instance in Toronto, *Makerbots*

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[10] *"Law Library Article."* American Pet Products Association. Accessed November 29, 2015. http://www.americanpetproducts.org/law/lawlibrary_article.asp?topic=62.

[11] *"Rear Support Dog Wheelchair | K9 Carts The Pet Mobility Experts."* Accessed December 2, 2015. http://www.k9carts.com/rear-wheelchair.

Figure 2. *FiGO* 3D printed joint pieces

are available to be booked at the *Toronto Public Library* for public use. [12] Spools of ABS and PLA (see Figure 3, pp.12) plastic cost roughly $45 USD at the time of writing [13], and *Makerbot* suggests that 1 KG spool can print up to 392 chess pieces. [14] While this does not give a measure of how much a spool can print in volume, it gives an estimation of how many *FiGO* pieces can be printed with one spool (each *FiGO* piece being no larger than 2-3 chess pieces) – using this data *FiGO* pieces that require printing could be produced for less than $5 USD. The other components of this specific pet wheelchair were acrylic tubing ($7 USD), straps to support the dog in the wheelchair ($3 USD), wheels ($5 USD) and fleece padding ($5), totaling in a material cost of $25 USD.

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[12] *"Digital Innovation Hubs 3D Design & Printing."* Accessed February 11, http://www.torontopubliclibrary.ca/using-the-library/computerservices/innovation-spaces/3D-design-print.jsp.

[13] *"Filament."* MakerBot. Accessed February 4, 2016. http://store.makerbot.com/filament.

[14] *"A Matter of Scales: How Much Can You Print with a Single 1kg Spool? (2012,February 24)."* Accessed February 11, 2016.

Figure 3. Spool of *Makerbot* ABS plastic

Design Choices

The *FiGO* 3D printed joint pieces were initially designed to imitate rounded plumbing fittings. It was discovered that geometric shapes were much more appropriate for 3D printing as they tend to stick more strongly to the machine bed, minimizing the potential warping of the piece. This also provided an interesting design aesthetic that further differentiated the joint pieces from plumbing fittings. The 3D printed pieces can be printed in a wide variety of vibrant colors. 3D printed nylon was explored as a possible material for this project due to

Figure 4. *FiGO* (photo courtesy of Pete Thorne Photo)

its flexibility and strength (see Figure 5, pp.13), but its inaccessibility to consumers and incompatibility with most consumer grade 3D printers lead to the selection of ABS and PLA as material choices for the project.

The wheelchair structure was built using clear acrylic tubing. While this is an appropriate solution for a smaller pet, what was later

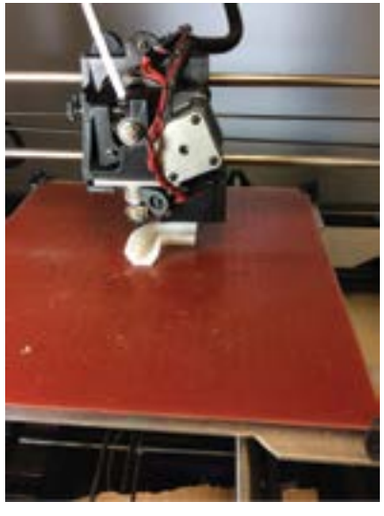
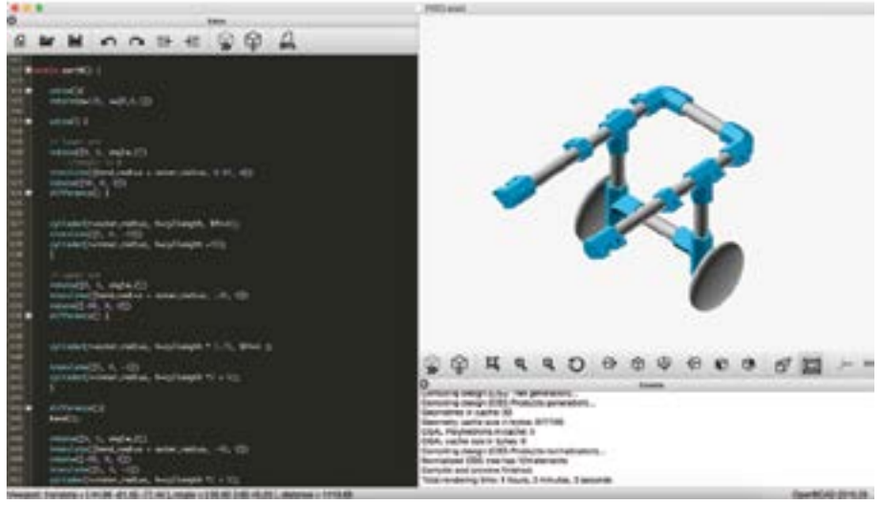


Figure 5. Nylon test print

learned from this process is that some pets will require different materials, depending on their weight and breed. A benefit from the acrylic is that it allows the end user to customize the aesthetic of the wheelchair , for instance by filling in the tubes with glitter or other craft materials; this is also called “soft customization”.

Finally, *FiGO* consists of parametrically designed components. The 3D printable joint pieces were modeled in *OpenSCAD*, an open source 3D modelling program developed for programmers (see Figure 6, pp.14). While there is a certain learning curve to the software, I thought it was relatively simple to learn and very effective when

Figure 6. *FiGO OpenSCAD* project file



designing parametric objects. In this case, parametric design means that the 3D model is prepared in such a way that users can simply change certain values, or variables, to alter the form. This means that users with no 3D modelling experience can easily engage with this design by simply changing number values in the design file.

The Thingiverse Platform

The *FiGO* project is currently published on *Thingiverse* where it can be accessed and downloaded for fabrication using a 3D printer. *Thingiverse* is currently the largest virtual 3D printing community, which makes it a great site for dissemination, awareness, and accessibility. I chose to publish the project on this online platform, where the project can be openly accessed by a wide audience, to gain a further understanding of risk management, and to learn more about

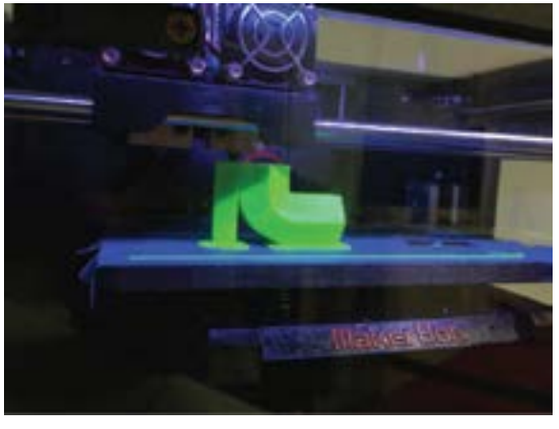


Figure 7. Hexagon shape print

what different users may need in terms of instructions to successfully build the project by themselves. In order to more smoothly transition into this platform, the design was adapted from previous iterations to ensure that it is a feasible project for novice users who do not have a designer or experienced maker close-by. For instance, 3D printable joint pieces that were once designed in an organic rounded shape were translated into hexagonal shapes to adhere more strongly to the print bed of the 3D printer (see Figure 7, pp. 15). Additionally, straps were adapted to be secured with screws to the 3D printed joint piece, as opposed to needing to drill through the structure with power tools.

Thingiverse enables users to adapt existing projects to suit their specific needs, provided that they have the knowledge required to amend a design. In *Patterns of Physical Design Remixing in Online Maker Communities*, the authors describe that while the ability to more easily customize (or remix) designs though *Thingiverse's Customizer* application has catalyzed a huge influx in design authors, designs produced through this tool are very rarely interacted with by members of the community once they have been published. [15] Other explorations of specific DAT expertise and participation in *Open Design* also indicate the need for designing in customization opportunities in a way that is enabling for novice makers. [16]

The design brief for *FiGO* (see Appendix A, pp.71) was used as a design probe in the research sessions to gain feedback from participants on how it could be improved to better communicate the project to the end user, as well as simultaneously encourage them to extend the project. It was then improved and evaluated by the same participants.

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[15] Oehlberg, Lora, Willett, Wesley, and Mackay, Wendy E. . *"Patterns of Physical Design Remixing in Online Maker Communities."* pp. 639- 648. ACM, 2015.

[16] Moraiti, Argyro, Abeele Vero Vanden., Vanroye, Erwin, and Geurts Luc. *"Empowering occupational therapists with a DIY-toolkit for smart soft objects."* pp. 387-394. ACM, 2015.

Lack of Feedback for Design Iteration

There seems to be very little engagement around improving and iterating on designs from members of the community (novice makers) that may lack technical expertise to produce novel designs.

Thingiverse has the infrastructure in place to allow users to post, share, and fabricate 3D printed projects via a project page which varies from a completely empty page with no added author information or guidelines, to elaborate DIY style step-by-step instructions. One aspect of the *FiGO* experience that *Thingiverse* is lacking is offering opportunities for dynamic interaction that a community such as the *Bunz Trading Zone* so effortlessly invites (spontaneous project initiation, community support, facilitated collaboration). *Thingiverse* could benefit from a space that would elicit impromptu connections to bring together end users, designers, engineers, and makers. In making practice taking place exclusively online, potentially complex projects such as DAT may require alternative forms of engagement with the project author such as video chat, or a dedicated collaborative space other than the written comments thread paired to a project page.

Literature Review

For this MRP, I explored the communication of instructions and processes, focusing particularly on the DIY maker movement and communities such as *Ikea Hacker* and *Instructables*, to gain a broader understanding on how a designer can communicate their DIY projects in the online context. I paired this research with an in depth study of *Thingiverse*, looking at design remixing and DIY Assistive Technologies.

Communication of Instructions and Processes

> "Literature in HCI, design, open source and hacking shows that sharing documentation about a project is caring for (future) participants, since it can enable them to learn from it, comment on it or appropriate it for other goals and groups, or even create new versions of it that they would not have been able to produce from scratch". [17]

There is a lack of research focusing on "methods by which project documentation is created and utilized". [18] DIY culture has presented the opportunity to personalize creations published by designers or other professionals on various media, particularly via online communities. As explored in *Making instructions for others: Exploring mental models through a simple exercise* (2013), Phillips et al. identify a link between the popularization of the Maker

[17] Schoffelen, Jessica, and Huybrechts, Liesbeth. *"Sharing is caring. Sharing and documenting complex participatory projects to enable generative participation."* (2013), 11.

[18] Tseng, Tiffany, and Resnick, Mitchel. *"Product versus process: representing and appropriating DIY projects online."* pp. 425-428. ACM, 2014.

Movement and the prevalence of Maker-generated tutorials and online communities that support them. [19] However, with that they also identify a clear lack of attention to the design of the tutorial itself. This resonates with Tseng and Resnick's work (2014) as they explore how "documentation and design often are two separate and often conflicting processes". Designer focus is more affixed to the design rather than the documentation of the artifact or process. [20] This presents as an issue as end users will not appropriate DIY projects that are meant to empower them to extend the design if they are faced with major barriers in understanding the project.

DIY Instructions

Dalton et al. (2014) research how online DIY tutorials could be formalized into a structured document that accurately displays all information required for the project. They perform a study of translating DIY tutorials into a cookbook recipe format, which is a well known structured approach to delivering instructions. Though the minimalist approach to recipe instructions wasn't fully compatible with the DIY format, it enabled them to explore how tools can be designed to "support DIY tutorials and peer-to-peer knowledge sharing". [21]

[19] Phillips, Robert, Lockton, Dan, Baurley, Sharon, and Silve, Sarah. *"Making instructions for others: Exploring mental models through a simple exercise."* interactions 20, no. 5 (2013): 74-79.

[20] Tseng and Resnick. *"Product versus process: representing and appropriating DIY projects online."* pp. 425-428.

[21] Dalton, Matthew A., Desjardins, Audrey, and Wakkary, Ron. *"From DIY tutorials to DIY recipes."* CHI'14 Extended Abstracts on Human Factors in Computing Systems (2014), 1410.

Wakkary et al. (2015) examined the quality of DIY tutorials by engaging in building them as a research group. Through this experience, they identified important components of a DIY tutorial that were present or absent in their chosen tutorials: "1) competences, components and tools; 2) sequencing, 3) and communication". [22] Findings resulted in guidelines reflecting a need to publish accurate information that does not omit tools or steps, the clear identification of all tools and components included in the tutorial, and the explicit identification of experience required for the project. The proposed guidelines also included the importance of carefully sequenced tasks, dividing the tasks into balanced steps, as well as using visuals to supplement text that use a consistent formatting. Their goal is to empower project participants to extend the work without needing much support from makers.

Schoffelen and Huybrechts developed a "thick documentation" approach in their study (2013) described as "an approach to documentation that can stimulate end-user development" in projects that their research group is involved with. [23] They look into documentation from a theoretical standpoint, researching various case studies of documented projects using 4 criteria:

[22] Wakkary, Ron, Schilling, Markus Lorenz, Dalton, Matthew A., Hauser, Sabrina, Desjardins, Audrey, Zhang, Xiao, and Lin, Henry WJ. *"Tutorial Authorship and Hybrid Designers: The Joy (and Frustration) of DIY Tutorials."* pp. 609 618. ACM, 2015, 613.

[23] Schoffelen, Jessica, and Huybrechts, Liesbeth. *"Sharing is caring. Sharing and documenting complex participatory projects to enable generative participation."* (2013), 9.

> "(1) how projects are currently documented on online platforms (media used, e.g. websites, texts, blueprints), (2) what kind of generativity they aim for (reuse, collaborative development, inspiration, reinterpretation), (3) how they approach subjective documentation (how they share the philosophy, visions, goals related to a project) and (4) how they motivate makers and participants to document". [24]

While they study a variety of domains in their case studies, Schoffelen and Huybrechts address documentation of open hardware (or *Open Design*) projects through one case, which is relevant to this paper. "These projects predominantly share (digital) blueprints of the hardware construction to enable both consumers and makers of hardware (e.g. diy hobbyists, companies) to download them, (collaboratively) modify them, with software and/or use them to produce via computer-mediated machines." While they propose this concept of generativity, they discuss the potential for subjective viewpoints on a project as they may provide subtle information that could not be accessed otherwise. This could perhaps exist in the form of testimonials in design documentation that guide the participant through the entire design process for that particular case. That being said, it was also identified that multiple viewpoints may confuse the reader.

IKEA Hacking

IKEA Hacking is a practice where designers publish designs of objects produced with components available at *IKEA*. Documentation methods that designers use when publishing their work are a great example of how a community enables participants to appropriate

[24] Ibid., 10.

and extend DIY projects. Rosner and Bean interviewed participants who design projects for IKEAhacker.com as well as participants who engage with the DIY projects and learn that "the standardization of *IKEA* products, rather than a creative constraint, is seen as a benefit to communication and sharing". [25] This shows how constraints can be seen as positive reinforcements for a sense of community and unison which can be potentially translated to the *Thingiverse* platform (which may prove to be more difficult considering the variety of 3D printers and filaments used in the fabrication of *Thingiverse* designs): "IKEA hacking points to the need for a more critical engagement with DIY culture and further reflection on the impact of online communities on identity and creativity". [26] Saakes (2009) also explores *IKEA* hacking by presenting a case study of their re purposed lamp design that was published to the *IKEA Hackers* website and became popular. They reflected through their experience criteria for requirements for designing DIY projects. Criteria included "getting to know your users as makers", "provide confidence", "make clear instructions", "check availability of materials and tools", and "take responsibility" for the design. [27]

[25] Rosner, Daniela, and Bean, Jonathan. *"Learning from IKEA hacking: i'm not one to decoupage a tabletop and call it a day."* pp. 419-422. ACM, 2009, 420.

[26] Ibid., 422.

[27] Saakes, Daniel. *"Big lampan lamps: designing for DIY."* pp. 403-404. ACM, 2009, 404.

Instructables

Instructables is an online community similar to *IKEA Hackers* in that it revolves around DIY making practices. Instructables, is a "community-based instruction [website], [where] instructions are posted and reviewed by users." [28] This community is more broadly geared towards makers of all kinds, and often features much more elaborate instructions than those you can find on *Thingiverse*. The featured project categories on the website include: technology, workshop, craft, home, food, play, outside, costumes. Albeit all DIY projects, instructions on this platform seem to vary in skill requirement. This platform could be attuned to DAT as instructions that are more thorough and require more knowledge to fabricate are well supported by this community.

Design Appropriation

Dix (2007) focuses his research on design appropriation and the importance of end user contribution to the design: "documentation can be enhanced by end-user contributed content. [29] It is important to consider the element of participation in the design process and how documentation can stimulate or prevent generative participation. Ehn (2008) explores concepts of participatory design and meta-design in the role of empowering end users by involving them in the design process. The way that a design is produced and communicated affords its adaptability and ability to be appropriated. Participatory design is grounded in the concept that "those affected by a design should have

[28] Druck, Gregory, and Pang, Bo. *"Spice it up?: mining refinements to online instructions from user generated content."* 2012, 545.

[29] Dix, Alan. *"Designing for appropriation."* 2007, 29.

a say in the design process". [30] In these types of projects, there is a particular need for representations or descriptions of what the design is meant to be or do, and how it is meant to potentially evolve. The author also presents the concept of meta-design which is similar to participatory design though it differs in the way the participation is being facilitated: "here both professional designers and potential users are seen as designers, much as in participatory design, but they are not participating in synchronous entangled design-games, but in design-games separated in time and space". [31] This process is much more in synch with the way that the *Thingiverse* platform is mediated. This meta-design process could inform how design briefs should be communicated to end users.

Digital Making Culture

Digital making could refer to the practice of making digital things, or making things using digital tools. *Thingiverse* is a space that encourages all of its users to make digital objects that can be translated into tangible objects via 3D printing, laser cutting, or CNC (computer numerical control) milling. It is an online repository for designs as well as a social network for DIY hobbyists and makers alike. Members of the community can publish their own designs or download and fabricate other user's creations by using digital fabrication tools (with the most popular method of production being 3D printing). The culture of making created by *Thingiverse* resulted in designs of all kinds being developed, adapted, and reproduced on the website in massive volumes.

[30] Ehn, Pelle. *"Participation in design things."* pp. 92-101. Indiana University, 2008, 94.

[31] Ibid., 96.

Design Remixing

Remixing on *Thingiverse* refers to the extension, amendment, or appropriation of a work designed by another user. An example of how this is facilitated on the site is its *Customizer* platform. *Customizer* provides users with a simple interface used to edit parametric designs produced in the popular modelling software *OpenSCAD*. Oehlberg et al. explore *Patterns of Physical Design Remixing in Online Maker Communities* in their study (2015). [32] They present that the introduction of the *Customizer* application has resulted in a huge rise in the number of projects on the site. They learned that designs customized through the *Customizer* application made 42% of the designs published on *Thingiverse*. Through a quantitative analysis of designs generated through *Customizer* they learn that "while parametric tools like Customizer allow more users to generate personalized objects, these designs end up isolated from the rest of Thingiverse". [33] They saw that generated designs were not often eliciting any user activity.

Do-It-Yourself Assistive Technology (DIY AT)

A number of designs of assistive technologies have been published by community members on *Thingiverse* in the form of blueprints (or DAT). Hurst and Tobias argue that empowering individuals to build or customize/personalize their own assistive technologies could improve adoption rates of assistive technology which are currently very low. [34] Their paper investigates the

[32] Oehlberg, Lora, Willett, Wesley, and Mackay, Wendy E. *"Patterns of Physical Design Remixing in Online Maker Communities."* pp. 639-648. ACM, 2015.

[33] Ibid., 647.

[34] Hurst and Tobias. *"Empowering individuals with do-it-yourself assistive*

potential for DIY assistive technology by presenting case studies in combination with interviews to gather insights on people's thoughts and experiences with customized assistive technology. They found that "online communities of others who have used, modified, or designed their own technology can provide valuable decision making information" for individuals who are in the market for assistive technology. [35] Finally, Hurst and Tobias believe that tools that can enable people to personalize existing designs will be crucial for the future of DIY assistive technology, which can be already seen by the rising amount of assistive devices being published on *Thingiverse*.

However, there are challenges associated with developing DIY assistive technology for an online design repository (or DAT) such as Thingiverse. Buehler et al. write in their paper (2015) that "many of [the DIY assistive technologies] are created by the end-users themselves or on behalf of friends and loved ones. These designers frequently have no formal training or expertise in the creation of assistive technology". [36] This poses challenges echoed by Hook et al. (2014) where health professionals were concerned that the average user may not take all the necessary precautions when designing or fabricating assistive technologies as they lack experience. [37] There are liability issues associated to this that Mota writes about in her paper (2011) suggesting that "it is very likely that these regulations, and mostly the burden of ensuring safety, will still lie on the providers of digital fabricators, materials, and blueprints— while alterations or misuses on

technology." pp. 11-18.

[35] Ibid., 18.

[36] Buehler, Branham, Ali, Chang, Hofmann, Hurst, and Kane. *"Sharing is caring: Assistive technology designs on thingiverse."* pp. 525-534.

[37] Hook, Verbaan, Durrant, Olivier, and Wright. *"A study of the challenges related to DIY assistive technology in the context of children with disabilities."* pp. 597-606

the part of the users will be their own responsibility". [38] This only further highlights the need for risks to be properly communicated in the design documentation, and for DAT to be approved by professionals specialized in assistive technologies.

However, online DIY platforms also provide several benefits including the fact that solutions may be produced for often a much lower cost without compromising robustness of the design in most cases. [39]

Summary

The research discussed in this paper addresses the issue that DAT need to carefully documented when published as blueprints on online design repositories such as *Thingiverse*. It identifies various approaches to documenting DIY designs that could be explored through their application to *Downloadable Assistive Technologies*. The research also addresses the unique circumstances associated with online design repositories resulting from the popularization of the *Maker Movement* as well as consumer 3D printers.

[38] Mota, Catarina. *"The rise of personal fabrication."* pp. 279-288. ACM, 2011, pp. 285.

[39] Buehler, Branham, Ali, Chang, Hofmann, Hurst, and Kane. *"Sharing is caring: Assistive technology designs on thingiverse."* pp. 525-534.

Environmental Scan

In designing the prototype of the *FiGO Pet Wheelchair*, it was important to do a market analysis of the existing commercial and open dog wheelchairs (specifically rear carts, as *FiGO* is a rear cart dog wheelchair). Particular attention was attributed to the documentation of the dog measurement process. Following are two tables outlining the advantages and disadvantages of each design as well as their product specifications.

Commercial Dog Wheelchairs

Product Profiling of Commercial Rear Wheel Dog Wheelchairs (See Table 1, pp. 31)

Open Dog Wheelchairs

Design Profiling of Open Dog Wheelchairs (See Table 2, pp. 33)

Summary

As commercial pet wheelchairs are mass produced with high quality materials, they are very expensive and can be unaffordable for many pet owners in need of the product. They offer a solid design and they are supported by veterinary professionals, but fall short in terms of aesthetic (and sometimes functional, such as the resizing of structural components) customization. Open pet wheelchairs are easily accessible as long as the user can source the proper materials and/or have access to a 3D printer and other tools. Parts and tools should be clearly described in the design brief. Open pet wheelchairs

offer a vast amount of customization options (both fit and aesthetic) but none scanned for this paper have explicit approval from a veterinary professional. Both commercial and open dog wheelchairs varied greatly in terms of extensive dog measurement and fitting documentation. *RollingPup* and *Eddie's Wheels* have proved to have the most robust dog measurement documentation. However, DIY instructions could be presented in a more user friendly way (for example, *RollingPup's* instructions separate visual support and text content so two documents must be followed simultaneously). A major fault discovered about 3D printed open dog wheelchairs is the lack of source files (design files developed by the designer in a 3D modelling program) included with the design or any ability to customize the 3D model.

Table 1.

Product Profiling of Commerical Dog Wheelchairs (Rear Wheel Carts)

Product	Materials	Features	Dog Measurement Process	Advantages	Disadvantages
Rear Support Dog Wheelchair K9 Carts (US) **$225.00 - $525.00 USD** k9carts.com	Aluminum frame Support saddle Rubber wheels	Convertible Design (converts easily from 2 to 4 wheels for added support) Adjustable Available in red, blue, and pink Padded for comfort	Visual diagram with 8 measurements overlaid on a dog in three perspectives	Adjustable design No customization required (thus quick turnaround for shipping) Adapts to dog's health condition by enabling user to add extra wheels for added support	Not many customization options other than a few colours to select from Not customized (adjustable design used for all breeds) Costly
Walkin' Wheels Mini, Medium, Large. Walkin' Wheels (US) **$249.00 - $459.00 USD** walkinwheels.com	Aluminum frame Support harness Foam wheels	Available in Pink, Blue, or Camo colours Wizard Process guides user through the purchase (from measurements to checkout) Available in mini,medium, and large sizes (supporting 8-150 pounds) Adjustable to accommodate different sizes	Graphic of dog with overlay showing a few measurements (height and fold of the flank)	Stylish wheelchair design No need to lift the dog into the cart No tools necessaryfor adjustments No customization required (thus quick turnaround for shipping) Detailed documentation on "How to tell if the Cart is Adjusted Properly" Folds Flat for storage	Since there is no customization, there are assumptions being made about all breeds of a certain weight class having the same requirements Measurement process not detailed Few colour choices Limited to the three colour choices Costly
Rear Wheel Cart Eddie's Wheels (US) **$325.00 - $600.00 USD** eddieswheels.com	Aluminum frame Support saddle Rubber wheels	Aluminum frame can be anodized a variety of colours Custom built to the dog WalkinWheels one-size fits all saddle secures dog in place	Graphic of dog in three perspectives with overlay showing measurement specifications Visual guide with 5 measurements outlined on the site including a video for support	Some aesthetic customization options Portable and storable User friendly website Custom solution means it will be a perfect fit to the dog	More time consuming process associated to customizing the chair (approx. 2 weeks) Costly

Table 2.
Design Profiling of Open Dog Wheelchairs

Design	Suggested Materials	Features	Dog Measurement Process	Advantages	Disadvantages
Dog Wheelchair (Thingiverse) by Thingiverse user "BlueOokami" thingiverse.com/thing:824774	No specifications	Three pieces (A,B,C) to be 3D printed and combined with aluminum tubing (?)	Photo of dog with annotations of where the 3D printed pieces should exist on the wheelchair	Empowers individuals to build their own dog wheelchair Easily accessible Inexpensive	No instruction on the process of measuring, fitting, or fabricating the cart No information about materials and where to source them from No source files included with design, or any options to customize
Rolling Pup Dog Wheelchair (Non-profit organization) rollingpup.com	Plumbing fittings (and PVC pipe) Wheels sourced from amazon.com Many tools	Plans for anyone to build the chair themselves Inexpensive and easily accessible components	Extensive instructions including documentation of the making process and measurement process Videos	Empowers individuals to build their own dog wheelchair Easily accessible Inexpensive Provides good instruction on the making process	Requires extensive knowledge of tools and making processes Not aesthetically pleasing No individual expression Instruction visuals and text are separate (you need to follow two documents simultaneously)
Adaptable Wheelchair for Handicapped Dogs (Instructables) Instructables user "aimzzz" instructables.com/id/Adaptable-Wheelchair-for-handicapped-Dogs/	Aluminum tubes Tube connectors (pluming fittings) Large format 3D printer	Visual DIY tutorial Kit combining 3D printed materials and non printed materials	Not specified	Empowers individuals to build their own dog wheelchair Easily accessible inexpensive Supported by an active DIY community	Must be printed on a large format printer (this was printed on a *Multec M420*) Solution is customized to a specific dog and is not currently adaptable to others Some information lacking, visual tutorial could use supportive copy Measurement process not specified No source files included with design, or any options to customize

Design Approach

Participatory Working Sessions

There were four phases of research in this study; a) a survey of literature on communication of instructions and processes, *Open Design*, and online DIY communities, b) a survey of existing DAT on *Thingiverse* looking at the documentation and constraints placed on the designs, as well as a survey of both commercial and downloadable dog wheelchairs, c) design and execution of a research study using the *FiGO Pet Wheelchair* as a design probe to explore the outlined research questions, d) refinement of the *FiGO Pet Wheelchair* design brief prototype based on insights learned.

The research draws on literature from human computer interaction (HCI), communication science, and design. Three sets of working sessions were conducted to explore the documentation of DAT through the lens of two different stakeholders: novice users that are also end users of the DAT (in this instance, they are a dog owner with a dog in need of a wheelchair), as well as a health professional with extensive knowledge on assistive technologies (in this instance, a veterinarian or pet orthopedist with knowledge on assistive devices for pets). The working sessions were designed to gather requirements for the new *FiGO Pet Wheelchair* prototype, engage the stakeholders to participate in the process of designing an improved design brief that could be applied to DAT, and to evaluate the design brief prototype developed from insights gathered in the previous working session.

The survey of existing research approaches identified many approaches to the research of instructions for DIY processes. Researchers have used case studies, participatory design activities, interviews, as well as a design probe in more rare cases. Data collected

is most often qualitative as it deals with the study of a culture, and thus requires a very human approach. That said, it is difficult to draw direct conclusions from previous work, but rather helps to support further exploration in the documentation of DIY designs, specifically designs of assistive technologies, produced online.

My research addresses the existing gap of research in the documentation of *Downloadable Assistive Technologies* on *Thingiverse*, which are growing in popularity on the platform. I argue that these DAT could potentially benefit most greatly from a structured set of guidelines of use and communication of risks in the form of a design brief. This research aims to explore how this brief could take form.

Research Study Design

This research study involved six phases between two streams of research that converge in key phases. In the first stream (Stream A), there were two sets of working sessions, one that explored design brief communication methods to gather design requirements, and one that was devoted to evaluating the design brief prototype that was ultimately developed from the participants' input from the previous working session. During the second stream (Stream B), running parallel to Stream A, data was collected from the researcher's interactions with community members of *Thingiverse* commenting on the *FiGO Pet Wheelchair* design page. There were also be two phases of analysis and one phase of surveying existing DAT. Research Ethics Approval was granted for this research under the file number **100643**.

Each working session lasted an hour and engaged different stakeholders in separate sessions. As a novice maker with an emotional motivation for engaging with *Downloadable Assistive Technology,* and as a veterinarian or pet orthopedist with a professional motivation to promote the health of animals, the participants were invited to explore *Thingiverse* engaged in a design exercise within this community.

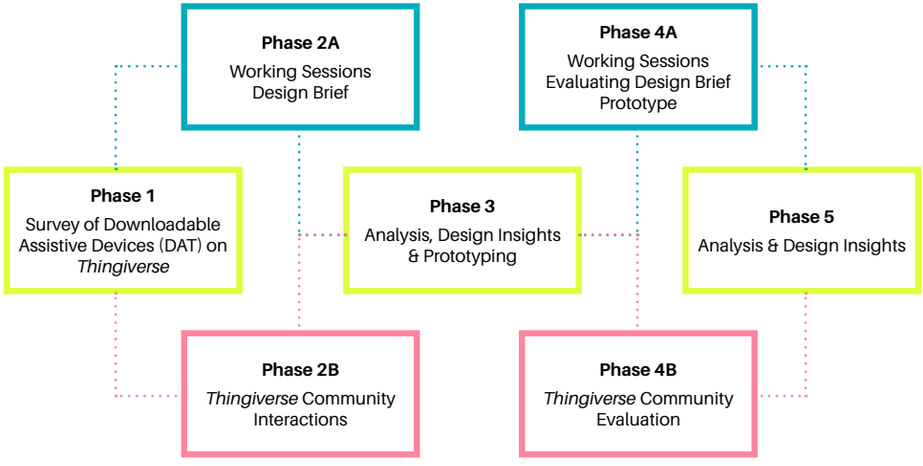

Figure 8. Research study phases

Through the working session activities, discussion, and interactions on *Thingiverse*, I gathered insights on how to meet the needs of non-designers in interacting with DAT (in this case particularly the *FiGO Pet Wheelchair*), and learned how I may improve the design brief process. I also gathered insights on the barriers non-designers face in this context.

Phase 1: Survey of Downloadable Assistive Technologies (DAT) on Thingiverse

In phase 1, I surveyed a selection of DAT currently published on *Thingiverse*. I specifically looked at what constraints designers are embedding into their digital files, what support the *Thingiverse* platform provides designers (for instance, looking at whether comments are the most common form of communication between designer and user), and if designers are communicating risks associated with their *Downloadable Assistive Technologies*.

Phase 2A: Working Sessions - Design Brief

During this phase, I invited a novice maker participant (dog owner) to idealize communication tools that could enable them to actively fabricate and participate in amending DAT. The participant was engaged in discussion around the current *FiGO* design brief to receive their input on the existing gaps in the project documentation. I also used this working session as an opportunity to gather requirements for the second prototype of the *FiGO Pet Wheelchair* that will be used as guiding project throughout this study. This includes physical requirements from the participant's dog as well as the participant's personal requirements for the function and aesthetic of the device. After the requirements were gathered for the wheelchair, it was fabricated for the participant and fit to their dog during Phase 4A.

This phase also included a discussion with a veterinarian to determine potential risks associated with the dog wheelchair, and to learn about how to communicate these risks to novice makers. The veterinarian was consulted with prior to the first session with the dog owner, so that risks were addressed prior to working with and fitting the dog wheelchair. The vet was provided with a detailed report on the outcomes of the working session with the dog owner as well as insights from the first prototype of the wheelchair.

Phase 2B: Thingiverse Community Interactions

During this research phase, I looked towards community members of *Thingiverse* posting on the *FiGO Pet Wheelchair* page, following the project being promoted as a featured design on the website (see figure 9, pp. 39). This included gathering feedback on the existing design as well as answering queries related to building the wheelchair or contributing to the project.

Figure 9. *FiGO* featured on *Thingiverse*

Phase 3: Analysis, Design Insights & Prototyping

In phase 3 I analyzed the collected data using thematic analysis informed by a grounded theory approach. Based on my findings, I established a set of design criteria for communicating risks and guidelines for use of DAT in the form of a design brief that is detailed in this MRP document. These criteria were used to produce a design brief prototype, which took form of a new project page on *Thingiverse* that could be used to educate users on the DAT, with the goal to empower them to fabricate and/or expand upon the design.

Phase 4A: Working Sessions - Evaluating Design Brief Prototype

In this phase, participants (both the novice maker and veterinary professional) interacted with the design brief prototype designed and published on *Thingiverse* based on the requirements gathered in the previous research phases. Participants were asked to provide feedback based on their experience using the tools. The dog owner received their customized *FiGO* wheelchair during this working session (see Figure 11, pp. 41).

Figure 10. Research station

Phase 4B: Thingiverse Community Evaluation

This phase included engagement with community members of *Thingiverse* posting on the new *FiGO Pet Wheelchair* page. I gathered feedback based on the presentation and content of the design brief.

Phase 5: Analysis & Design Insights

The final phase of my research involved a theoretical analysis of the data collected during the working sessions as well as the analysis of data collected from community interactions on the *FiGO Thingiverse* page. This analysis was used to refine the design criteria for communicating risks and guidelines for use for DAT. It was also used to refine the existing design brief prototypes and recommend future work.

Figure 11. Dog owner's customized *FiGO* wheelchair

Recruitment of Participants

Two participants recruited in total for this research: one participant that is an end user of DAT (owner of a dog in need of dog wheelchair), as well as one veterinary professional. There was no specific requirement for age or gender in this study.

For this research study the following two types of participants were recruited:

1. Owner of a dog in need of a dog wheelchair
2. Veterinary professional

Eligible participants met the following criteria:

1. Dog owner must be a novice maker unfamiliar with digital fabrication
2. Veterinary professional needs to have knowledge of a dog's health
3. Participants must be located in the Greater Toronto Area or are available to meet online via Skype

Recruitment Procedure

The dog owner was recruited through the *Bunz Trading Zone*, a popular Greater Toronto Area *Facebook* Group that brings together a community of locals that are interested in trading services, goods, or recycling their belongings. [40] The veterinary professional was identified online and recruited via email.

Data Collection

Data collected consisted of notes, photos of the working sessions, and audio recordings. Working sessions will be recorded using an audio recorder. The audio recordings were reviewed after each working session to document any statements that may not have been noted during the working sessions.

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[40] *"Bunz Trading Zone."* Accessed January 4, 2016. http://bunz.com/.

Research in Practice

Through participatory working sessions with the dog owner and veterinary professional, issues of communicating the design brief for the *FiGO Pet Wheelchair* design probe were openly discussed, addressed, and evaluated. The study consisted of two sets of separate sessions, two with the novice maker (dog owner), and two with the health professional (veterinarian). The first set of co working sessions took form of a discussion of the first prototype of the *FiGO* design brief, and the second set of sessions were dedicated to evaluate the adapted prototype developed from insights gained in the previous sessions. Criteria for the communication of DAT were developed, supported by literature, research sessions, and interactions on *Thingiverse*.

Figure 12. Dog owner's *FiGO Rear Support Pet Wheelchair* (photo courtesy of Pete Thorne Photo)

Outcomes and Analysis

Survey of Downloadable Assistive Technologies on Thingiverse

In my survey of existing DAT on *Thingiverse* (see Table 3, pp. 45), I came across a range of projects that were very poorly communicated to the end user (i.e. simply a file to download with no description). That being said, I did locate several projects that have implemented what seems to be very strong communication elements that could exist in the DAT design brief. Two larger themes were used to categorize these elements: content, and interface design.

Table 3. Survey of *Thingiverse* DAT

Content	Interface Design
Strong imagery	Custom Section Headers
Customizer App Functionality (source files compatible with Thingiverse Customizer)	Markdown language (http://www.thingiverse.com/thing:906745)
Personal experience with project	Keep an update log (http://www.thingiverse.com/thing:21486)
Include recommended parts if modular project (http://www.thingiverse.com/thing:1064647)	Table of contents (http://www.thingiverse.com/thing:906745)
Explain design use (http://www.thingiverse.com/thing:1064647)	Links to materials (http://www.thingiverse.com/thing:943096)
Explain project history (http://www.thingiverse.com/thing:1064647)	Design Remixing
Videos enhance presentation (http://www.thingiverse.com/thing:1090461	
Add disclaimer if necessary (http://www.thingiverse.com/thing:906745)	
Tools list	

FiGO Project Page Comments

In parallel to the working sessions was the collection of interactions on the *FiGO* documentation page on the design's corresponding project page on *Thingiverse*. Comments on the page, in the form of user feedback and clarification on the instructions, were divided into recurring themes: measurement taking, materials, and structural improvements. Interestingly, a majority of the comments were simply expressing enthusiasm or excitement in the project (i.e. "Cool design!", and "Your chair looks a lot easier to make that the one I was thinking about making."). A few *Thingiverse* members commented that they were building the *FiGO* wheelchair.

Material Comments: These comments reflect clarifications on material use, as well as suggestions for alternative materials. Comments were guided specifically to materials external to 3D printing (components that are not digitally fabricated), such as the structural tubing. A user whose spouse is a vet with her own practice suggested an alternative material that they will be using in their *FiGO* wheelchair: "I suggest you replace the acrylic with PETG tubing." Members of *Thingiverse* wanted a simplified bill of materials, as well as simplified calculations for tube lengths based on pet size. One user offered their help to complete this task: "Did you consider making a spreadsheet to calculate correct pipe lengths, depending on dog length, height and width? If not, I will do this and share it. Will take some weeks until I have time though."

Measurement Taking: The pet fitting process seemed to be one of the most complex aspect of this project. Measuring a pet properly is not a simple task, and member comments reflected this: "Could you be a little more clear on the dog measurements for the spreadsheet? Height is top of the dog's body to the floor? Length starts where? "Belly" is a little vague for me." There was an added suggestion to this thought to incorporate a visual representation of the measurements.

Structural Improvements: These comments reflect suggestions on how to improve the structural components of the project. One stand out comment discussed using the chair for a dog that needs front support rather than rear support. The design currently does not accommodate this, but its modularity could support this functionality in the future.

Co Design Working Sessions

The co design working sessions generated some very insightful feedback in how to further improve the communication of DAT on *Thingiverse*. Several observations were made that mirror themes from both the survey of *Thingiverse* DAT as well as the user interactions on the *FiGO* project page. Both co design working sessions made use of the *FiGO* project page as a design probe to inspire generative comments and suggestions to improve the *FiGO* design brief (see Appendix A, pp.71).

The first co design working session was conducted with the veterinary professional. Interestingly, there was immediate pull to the design itself rather than the display of information in the project page. They critiqued the strap system to be more adjustable. They demonstrated samples of work that were similar to my design, albeit designed with a much different, less sustainable, process. The discussion was focused on material. We discussed 3D printed nylon and how it is strong, flexible, and can be dyed for aesthetic purposes. The veterinary professional pointed out that 3D printing affords better design capability and customization, but is simply not as cost effective as mass producible commercial designs. They also made some design suggestions around the use and adjustability of straps in the design, as well as the screws securing the straps to the frame of the wheelchair. They agreed that commercial pet wheelchairs ask for too many specific measurements from pet owners that the work actually tends to lose measurement accuracy. They were pleased to notice that the measurement process for *FiGO* involves a simple three measurements. Finally, they agreed that the design seems very safe and strong, and that everyone will want to try this project for the sheer price compared to expensive commercial pet wheelchairs.

The second co design working session was conducted with the dog owner or novice maker. Using the design probe as a sequential guide to the conversation, the participant made observations and discussed areas in which the *FiGO* design brief could be improved for their understanding of the DIY project. First, they wanted a more robust materials list that included *Amazon.com* links to the items listed. They also noted that "if someone doesn't necessary have the background to know what types of files these are, it might be confusing. If you are writing this in terms of having everyday Joe, then just simplify it a little bit in terms of the file names, and some of the instructions." The participant was also confused by the math equation for the wheelchair, and hadn't noticed the accompanying excel spreadsheet that automates these calculations. Unsurprisingly, they were very interested in seeing an annotated *IKEA* style visual step-by-step guide in the design brief for piecing together the wheelchair. The participant did not think a video would enrich the design brief, explaining it could confuse the end user. They would rather spend the time to follow a step-by-step guide than to constantly pause a video. Lastly, they were interested in showing that a vet approved of the project to add credibility to the DAT. This session also included measuring the participant's dog in order to fabricate his wheelchair. The participant insisted to measure their pet due to their pet's anxiety.

Literature

In conjunction with these working sessions, the following principles were taken from literature to formulate design criteria for the design brief of a DAT on *Thingiverse*:

- Support peer to peer knowledge sharing (Dalton et al.)
- Instruction structure of 1) competences, components and tools; 2) sequencing, 3) and communication (Wakkary et al.)
- Stimulate end user development (thick documentation) (Schoffelen and Huybrechts)
- Include end user content (Dix, 2007)
- Encourage participatory design (users should have influence on projects that affect them) (Ehn, 2008)

Feedback from both the end user and veterinary professional enabled a very heavy redesign of the *FiGO* design brief (see Appendix B, pp.75) that included the following additions to the original prototype:

- A change of name from the *FiGO Dog Wheelchair* to the *FiGO Rear Support Pet Wheelchair*, to be more clear about the design and its function
- Uploaded all source files (*OpenSCAD*) so that *Thingiverse* community members that have skill in 3D modelling can take their hand at adapting the design.
- Enabled *Thingiverse's Customizer* functionality so that users can easily make simple tweaks to the original design to suit their pet. (see Figure 13, pp. 52)
- A table of contents for easy navigation
- A brief history of the project
- An improved materials list including links to purchase them on *Amazon.com*
- A tools list
- A simple guide on measuring your pet with visuals
- A simple spreadsheet that does the calculations for the user needed to determine the size of the acrylic tubes needed
- A comprehensive visual step by step process for building the frame and adding the wheels and straps.
- A section for testimonials
- A notes section depicting my personal experiences with fitting dogs, and recommending end users consult with their vet while working on the project
- An update log

Evaluative Working Sessions

Following the update of the *FiGO* design brief, two evaluative working sessions were conducted with the same research participants. Further improvements to the *FiGO* design brief will be be embedded in next iteration based on the outcomes of these sessions.

The third working session with the veterinary professional further addressed design details that they seemed could be refined to improve the project.

The fourth and final working session with the dog owner was a more detail oriented session revisiting of the adapted design brief prototype. The participant had further insights to improve the communication the of design brief, specifically the order of the information. This session also included giving the participant their *FiGO Pet Wheelchair* for their dog. Unfortunately, I had to quickly tweak the wheelchair as the sizing was off due to imprecise measurements. Finally, they expressed interest to go home and further personalize their chair.

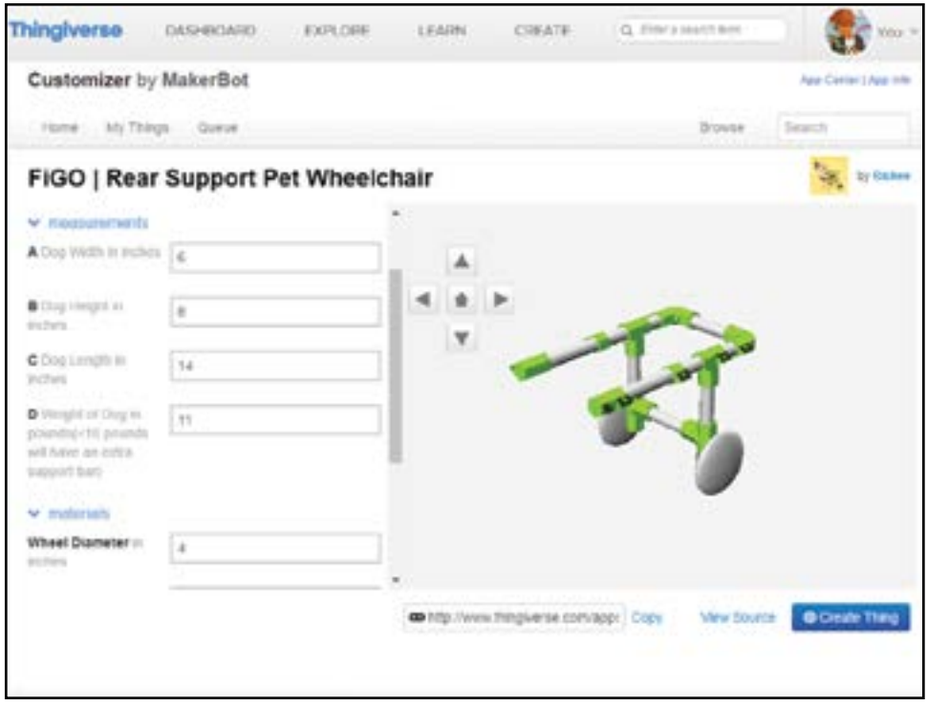

Figure 13. *FiGO Customizer*

Findings

Firstly, it was found that the *FiGO* project is a viable competitor in the pet wheelchair market. Both participants loved the visual design and the cost effectiveness of the project.

The combined research efforts detailed above resulted in the refinement of the *FiGO* design brief. Mechanisms collected from multiple sources of refinement explored benefited the project. Diversity is key in the *Inclusive Design* process to steer away from concept of the echo chamber (an enclosed context where repetitive information is intensified, dulling less represented views), to diverse sources of information. [41] The veterinary professional was mostly fixated on the design itself rather than the communication of the design, which could be a testament to his interest in design and ability to fabricate assistive technologies, since he develops prostheses and orthoses for animals on a regular basis.
In the case of the dog owner participant, the working session location was key, as I was able to demonstrate how I made the wheelchairs in my studio.

The role of veterinary professional was guided towards the assessment of risks and safety of the project, and bringing those assessments into the process of developing the DAT design brief. Risks are difficult to assess in a DIY project as it is impossible to know or control what tools or materials the end user is using for the project (what printer they are using, what type of 3D printing filament, the quality of their print, etc.). In such a situation, material testing becomes virtually impossible. That being said, further risk assessment and durability tests will be performed in the future that weren't included in this study. For this study, risks were considered in terms of communication.

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[41] Treviranus, Jutta, and Stephen Hockema. *"The value of the unpopular: Counteracting the popularity echo-chamber on the Web."* 2009.

It was found that *Thingiverse* behaves like an echo chamber. It has become a space for makers to share their digital fabrication projects, but offers little space for users to seek support in the design or fabrication process of *Downloadable Assistive Technologies*, as well as the many other designs published on the platform. DAT on *Thingiverse* are met with a great deal of enthusiasm and encouragement by many users, but seemingly health professionals are not playing at active role on the platform in any capacity. Users on *Thingiverse* can download and fabricate anything published on the website, but they lack the support of the knowledged designer, individual, or professional. *Inclusive Design* suggests that the end user be part of the design process, so that designs are inclusive from their conception and not as a retrofit. *Thingiverse* does not yet encourage participatory/co design, and thus lacks many benefits that exist when designing with the end user in person. The very intimate, inclusive participatory/co design is much different than its online counterpart of *Open Design,* as it includes the end user during every step of the design process.

Thingiverse tries to mitigate this lack of communication and connection by allowing makers of designs to add thorough descriptions in the form of instructions or tips in their design's project page. Designers and makers may also communicate with users via the comments section of their design. What this process lacks is dynamic interaction and feedback.

When designing with the end user in person, instructions are a non-issue, as the professional and end user work together throughout the entire design process.

Discussion

Challenges Identified

During this Major Research Project, various challenges and limitations were identified. Firstly, my skills as a designer were quickly taken for granted. DIY instructions need to be extremely clear of every angle of the design. I would argue that non-designers need to play an active role in the iteration of DIY project instructions, as designers are limited with the assumption of their reader's skill level. The end user needs to actively participate in this iterative process.

Additionally, It was also learned that due to the fact that dogs have their own personality, it is difficult to predict whether or not a dog will respond well to a wheelchair fitting. In this case, the dog was anxious, and as a result was measured by the participant. The participant provided measurements that were slightly too large, which shows that not all users may measure properly, even with proper instruction. Luckily adapting the design is very easy, so incidents such as these can be easily remedied. A professional is trained and has the tools to react to uncontrollable or unforeseeable situations, whereas the end user may lack knowledge in the area. That being said, the end user will likely also have a better understanding of their pet than a professional can assess in a short visit.

Provided that the interactions with dog owner were personal, it is also seemingly probable that interactions solely based virtually would suffer from lack of constant communication and feedback. The personal, human component seems to be key for success of this project. Research must be further done to learn how to supporting such personal connections online.

Another limitation to this work is that the *FiGO Pet Wheelchair* was designed within the manufacturing constraints of a consumer grade 3D printer and locally sourced materials. This design is much different than what it could be if it was just produced in a more traditional method (by the designer for the end user). *FiGO* was also designed by working with only small dogs. As this research was not working with people, one can only can take the recommendations so far. This study used the model of a non human as an example for other experiences that can be conceivably the same.

A large portion of the community interaction with DAT are attracted to DIY projects, but are not necessarily making them. It is much different than a community like Instructables where there are seemingly different expectations from the community (more complex projects, multi-material designs, longer fabrication processes).

Lastly, the question of liability issues still remains. Currently, a legal disclaimer explaining for the user to consult with their local veterinarian is the only form of protection for the designer and end user.

Considerations and Recommendations

Ehn's writing on the need for representations or descriptions for what the design is meant to be or do, and how it is meant to potentially evolve served as a guiding message in the generation of criteria for communicating DAT, which then informed the adapted *FiGO* design brief. [42]

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[42] Ehn. *"Participation in design things",* 94.

Wakkary et al. (2015) developed guidelines or important components of a DIY tutorial "1) competences, components and tools; 2) sequencing, 3) and communication". [43] The proposed guidelines included the importance of carefully sequenced tasks, dividing the tasks into balanced steps, as well as using visuals to supplement text that use a consistent formatting. Their goal, much like in this work, was to empower project participants to extend the work without needing much support from makers. In addition to their components, I believe there are further considerations to be made when the DIY project is a DAT. First, I think it is important to humanize these assistive technologies, as opposed to medicalizing them. There is a huge stigma associated with assistive technologies that must be broken down. Designs have stories, and designers should tell these stories and encourage end users to share their own as well. I believe that we also need to eliminate the assumptions we make about what the user wants. We must involve the end users in every step of the process, including that of developing instructions for DIY projects. Additionally, clear instructions about the use of the design are important when the design has a direct impact on the health or wellbeing of an individual. Lastly, DAT should include source files in their design briefs in order to encourage participants to extend or customize the design to their specific needs.

Based on the above research, the following criteria for communicating DAT were synthesized and implemented into the adapted *FiGO* design brief in the *Thingiverse* project page (see Appendix B, pp.75).

- Tell the story of the design
- Do not make assumptions about the end user
- Clear instruction about the design use

[43] Wakkary, Schilling, Dalton, Hauser, Desjardins, Zhang, and Lin. *"Tutorial Authorship and Hybrid Designers: The Joy (and Frustration) of DIY Tutorials."*, 613.

- Inclusion of source files to enable user participation and extension of the design
- Strong visuals to accompany textual information
- Brief, balanced step-by-step instruction
- Content organized is a readable and user-friendly way

Thingiverse is not exclusionary, but it is rather exclusive. While *Thingiverse* nods towards inclusion by offering a service such as *Customizer*, where the rather complex *OpenSCAD* interface is simplified into a very readable and friendly user interface. There is certainly an inclusive intent on their part. That being said, it is not a platform for individuals who are not familiar with fabrication, and thus limits its pool of potential users. Communities like *Instructables* tackle this issue by standardizing a certain level of quality of instructions on their website. Unfortunately, *Thingiverse* DAT currently are not inclusively communicated to the end user. In my MRP research, I developed a rich, visual set of guidelines and instructions to build one's own pet wheelchair. I also actively took responsibility to respond to comments on the design's project page. If the designer of the DAT isn't proactive in the way they document their work, or does not participate in the comments section of their project page, end users are left without any support when fabricating or using DAT.

Thingiverse hasn't yet reached stability, and certainly hasn't aligned with the changing needs of this community that is now actively supporting the publishing of assistive technologies. The *Thingiverse* platform needs to support the end user more, in perhaps indirect ways. Thingiverse currently hosts a space dedicated to social interaction on their website called *Thingiverse Groups* (see Figure 14, pp. 60). [44] However, *Thingiverse Groups* is not widely used and is difficult to access in their user interface. The only function of *Groups*

[44] *"Thingiverse Groups."* Accessed February 10, 2016. https://www.thingiverse.com/groups.

is to hold conversation with other members. I believe there is much more potential to develop a social community focused on making. The *Bunz Trading Zone*, hosts a community that bands together to solve problems, offer advice, and to support one another. [45] The *Bunz* also acts as a fantastic platform for spontaneous project initiation, which is something that is currently very lacking on *Thingiverse*.

A proposed redesign of *Thingiverse Groups* inspired by the *Bunz*, *Thingiverse Projects*, creates a digital space for co design or participatory design that is currently lacking in virtual digital fabrication communities. This service is intended to address the gap in social maker communities online of linking people to collaborate remotely. This will enable users to aggregate solutions from around the world, which will not only strengthen but also diversify solutions to design challenges. While these kinds of collaborations and interactions may exist in other communities, such as the *Bunz*, *Thingiverse* is the most practical target community for this initiative, as it is already flourishing with eager members who love to make things and solve design problems. This enthusiasm needs to be harnessed and properly facilitated with a dedicated project collaboration platform that will encourage an even more diverse set of users to join in the making process.

[45] *"Bunz Trading Zone."* Accessed January 4, 2016. http://bunz.com/.

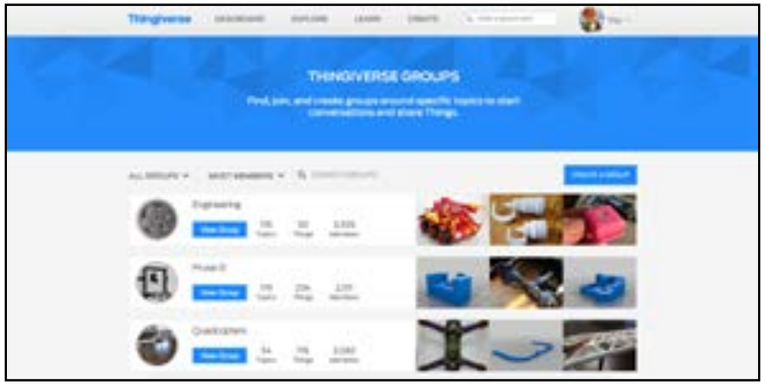

Figure 14. *Thingiverse Groups*

Implications and Contributions

Significance of Research

This research proposes a framework for communicating *Downloadable Assistive Technologies* on *Thingiverse* via the design brief. This study made contributions to the field of *Inclusive Design*, by considering participatory design in the process of designing DIY project instructions for assistive technologies published on the web.

The purpose for this study was to improve our understanding of communication tools used to brief DAT so that designers using platforms such as *Thingiverse* can publish their designs under principles that include assessment of risks and information on the application of the design (guidelines for use).

Other benefits associated to the development and refinement of the *FiGO Pet Wheelchair* and its design brief include the opportunity for individuals who need a dog wheelchair to access one (internationally) on *Thingiverse* at a very low material cost, instead of opting for an expensive commercial chair.

The original contribution of this research is that it specifically addresses the ever-growing digital fabrication platform *Thingiverse*, with a focus on assistive technologies uploaded to the site. Previous research has explored methods to document DIY tutorials and documentation on other platforms like *Instructables* and *Ikea Hackers*, and there has even been some research on the *Thingiverse* platform. What is lacking is the attention to this trend of assistive technologies being uploaded on *Thingiverse* to be fabricated, customized, and

potentially remixed. This research outlines the specific design criteria for documenting the project associated with this practice.

This work also highlights the offline aspect of co design. The interactions from the participatory design sessions in person differ greatly from the interactions that took place solely online. In person, individualized customization was achieved through discussion and iteration with the end user. Online, the designer is limited to publish their design as is, or to provide options for end users to slightly modify the design to personalize it to their specific needs. Further, there is no requirement set by the platform to include any of these options. Seemingly, virtually customized designs (open designs) dull in comparison to designs customized individually to the end user, where they are included during each step of the design process to ensure the design suits them personally. On *Thingiverse*, customization is much more spreaded as there is more distance between the designer and end user and there must be further work to research how to address this online barrier to participatory design.

Future Work

The research in this study explored how *Downloadable Assistive Technologies* could be communicated to end users on the online digital fabrication community *Thingiverse*.

There is a need for further research on how to mitigate liability issues by developing a system for health professionals to rate, test, and endorse DAT designs. Perhaps this exists as a platform for experts, not to replace them but to involve them, designing an opportunity to learn how to print and customize these objects for clients in their practice.

Future work will also include designing a *FiGO* wheelchair that can be properly scaled with higher end materials and finishes. This research identified that this project exists differently as an assistive technology fabricated by a designer as opposed to an end user.

It would be beneficial for future research to explore the disparity between DIY and engineered products, and how end users can be more directly involved in the process of building their assistive technologies without having to have direct design knowledge themselves. While this has been explored through participatory and co design, online communities such as *Thingiverse* have the potential to scale participatory design potential and make it even more accessible for end users to personalize and even design their own DAT.

The distance between designer and end user is huge in the context of open designs, which is effectively the opposite of *Inclusive Design*, where the user is intimately involved in the design process. Due to the current nature of the *Thingiverse* platform as an exclusionary community, this research will be an ongoing process. I see my role as a designer in this context as an agile responder to feedback and suggestions from end users, continuously iterating on the design as well as its customizability, by using *Inclusive Design* principles to enhance the accessibility of *Thingiverse's* interface. That being said, when does the involvement of a designer end, and what marks this exit in the process of designing open, downloadable designs? When are DAT designs complete? In the future, it would be interesting to research how to track and understand the wide spread of DAT on the *Thingiverse* platform and beyond.

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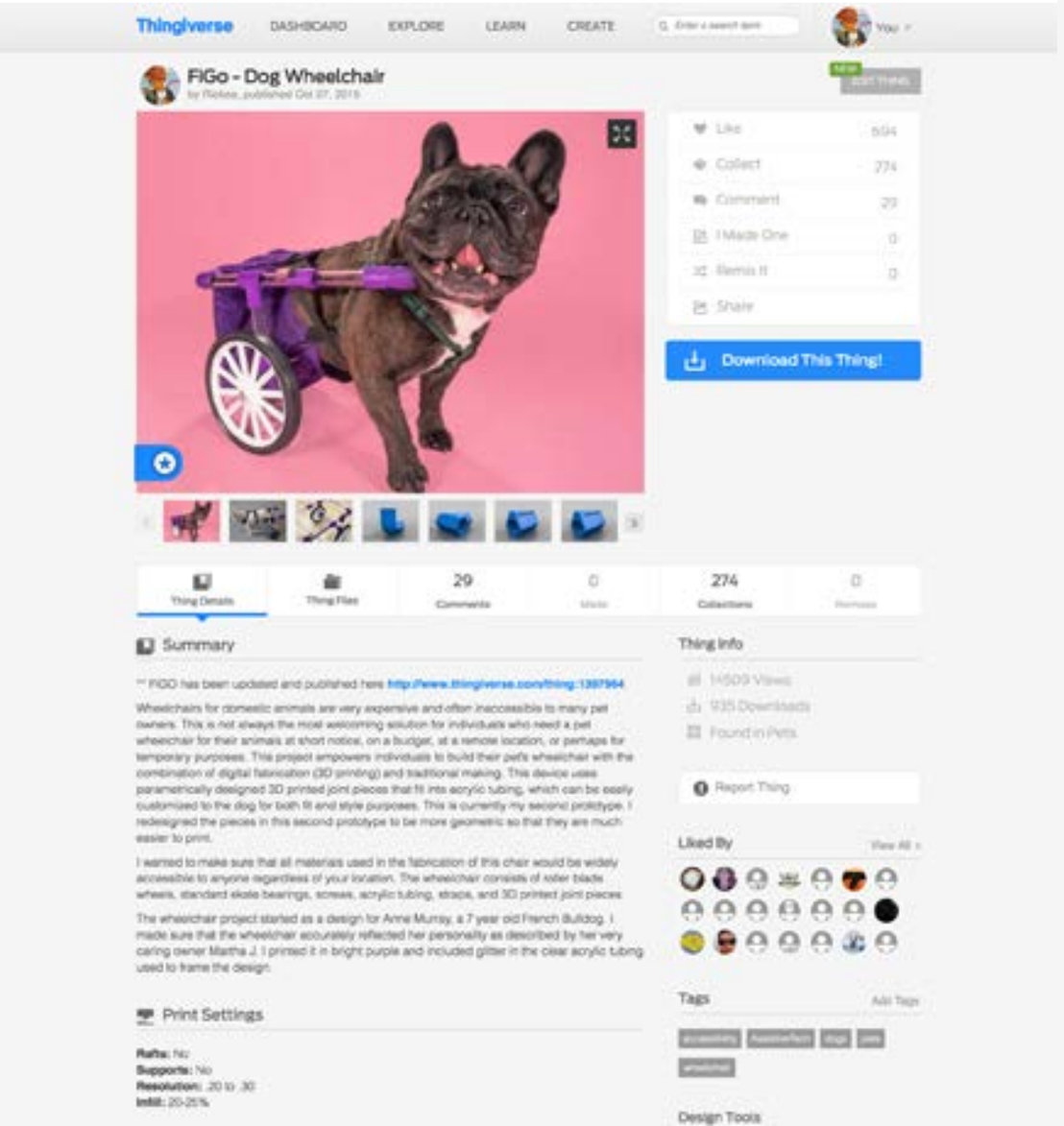
Appendix A: FiGO Design Brief

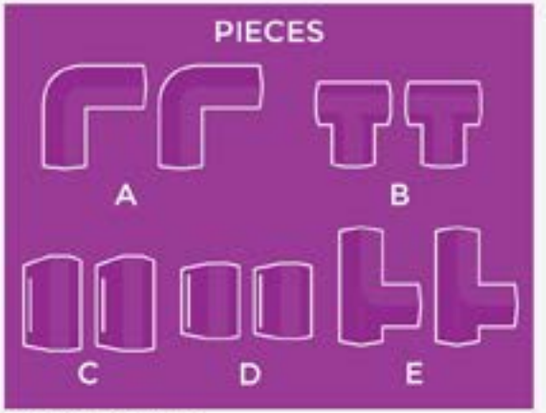


Print Settings

Rafts: No
Supports: No
Resolution: .20 to .30
Infill: 20-25%

Notes:
Print 2x of each piece (A,B,C,D,E) if you want to print the pieces with the exact outer diameter of the acrylic tubing (0.75") I have suggested, I have made those pieces available as well is "pieceA_exact.stl". Since there is some slight warping that occurs while printing, you may be more comfortable printing in the adjusted size that is slightly larger to accommodate the acrylic tubing with more ease "pieceA_adjusted.stl. Just make sure to choose one format and remain consistent with all pieces. With exact sizes, you will likely need a heat gun to heat up the piece and then quickly insert it into the tube. This will fuse the two pieces together. With adjusted sizes, you might want to use glue (gorilla glue works well) to ensure the tubes will not be loose. This may not be an issue if you have a dog that weighs less than 10 pounds. My client was a 30 pound Frenchie!

Post-Printing



Assembling the Dog Wheelchair
I used 0.75" inner diameter acrylic tubing to make the frame for the dog wheelchair. These 3D printed parts simply support this structure. The length of each tube will depend on your dog's width and height.

There are three different lengths of acrylic (or aluminum) tubing needed:

2x Acrylic tube the same as your dog's width.
2x Acrylic tube the height of your dog minus the radius of your chosen wheel, minus 1"
2x Acrylic tube the length of your dog from their belly to their tail, minus 2"

I have created a simple google spreadsheet that does these calculations for you as you input your dogs measurements. I am working on a web application that has this function, but this will do for the meantime! https://docs.google.com/spreadsheets/d/1OiiDn6DBQ-ios-n9due-AFACkuIDrC4GsDnRE2huNso/edit?usp=sharing

I also purchased two roller blade wheels and two standard skate bearings (the wheels pictured below were part of prototype #1, see photos above for new wheels). In order to support the wheels I used two screws ([1/4 - 20] x 3") fastened with a nut to the bearing and acorn nut to the 3D printed piece E.

Finally I purchased one strap from my local hardware store that is placed into piece D to support where the back legs (flanks) meet the body of the dog. I also purchased two velcro straps that feed through piece C to attach directly to your dog's existing harness. I am still working on a way to improve the connection of the piece to the harness!

Tags

Design Tools

License

Give a Shout Out

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Print Thing Tag

Assembly diagram

Acrylic tubing

How I Designed This

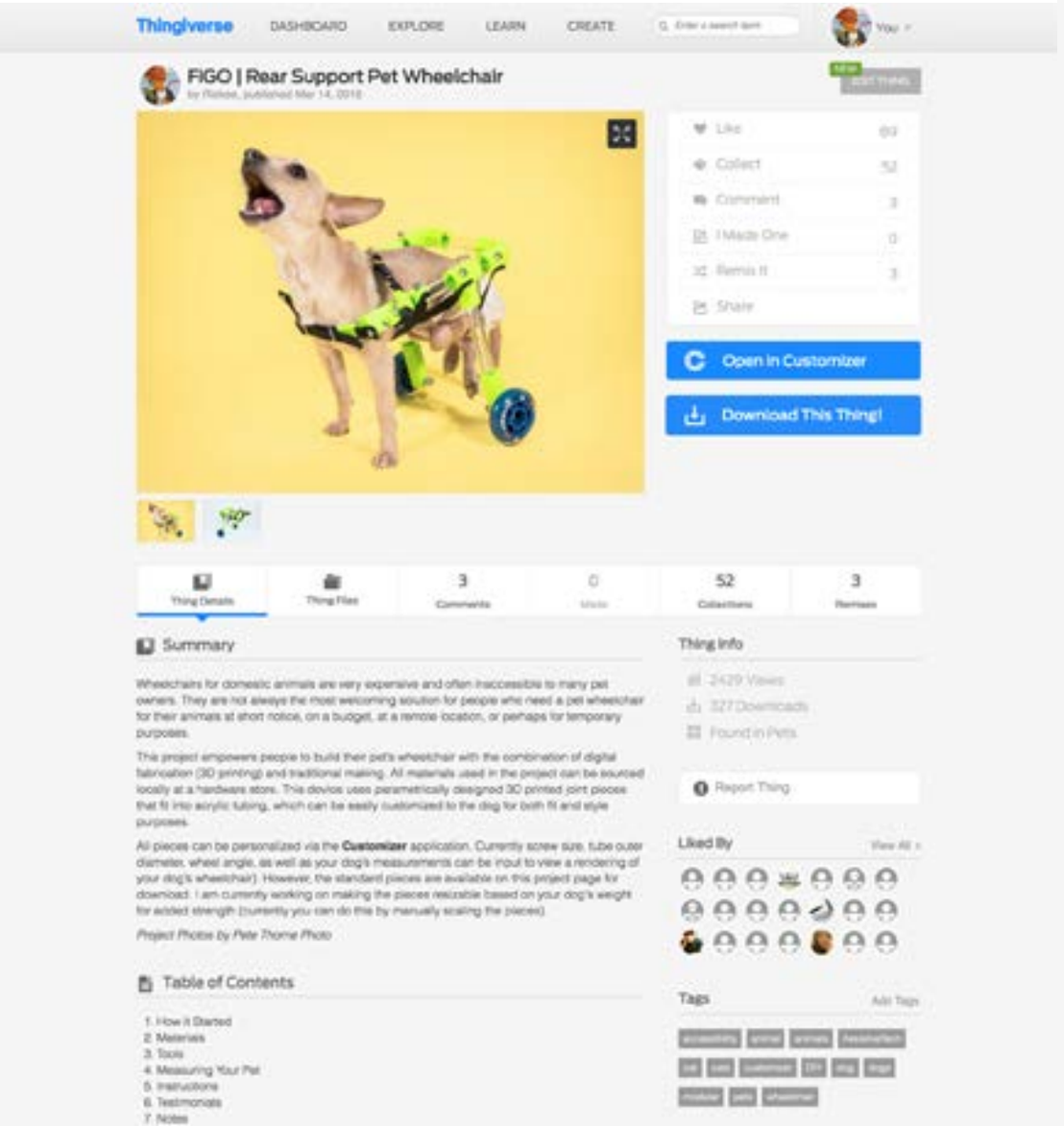
I designed this wheelchair using OpenSCAD so that the models can be adjusted to the size of tubing you have access to. I'm still currently working on this document (it is rather messy and needs to be polished) but I will make it accessible to everyone once it is prepared. This way you don't have to use 0.75" inner diameter acrylic tubing exclusively (even though I have tested many sizes and concluded that it is the best size for strength/weight ratio).

I am still heavily prototyping this design. I welcome all of your comments and suggestions! Thanks!!

More from Pets

view more ›

Appendix B: Adapted FiGO Design Brief



Project Photos by Pete Thorne Photo

Table of Contents

1. How It Started

FiGO began when I answered a call online for a friend who needed a wheelchair for their French Bulldog at short notice. They were unable to afford the costly commercial wheelchairs available online. I rose to the occasion to design something for an adorable dog, and the results were fantastic! Murray loved her chair!

Since then, I've built two other chairs for dogs, and I've worked on iterating the FiGO design and documentation to encourage all dog owners to tackle this project for their pet in need.

2. Materials

All materials used in the fabrication of this chair can be sourced locally at a hardware store or online via Amazon.com. The wheelchair consists of roller blade wheels, standard skate bearings, screws, acrylic tubing, straps, and 3D printed joint pieces.

- 10x — **3D Printed Pieces in Makerbot Filament** (PLA or ABS)
- 5-6x - **Acrylic Tubes** (5 tubes if dog is 10 pounds or less, otherwise 6)
- 5-6x - **Aluminum Tubes (alternative to acrylic tubes)**
- 2x — **Wheels** (larger wheels are recommended for dogs over 15 pounds)
- 2x — **Standard Skate Bearings**
- 2x — **Dog Collar** (slightly larger than dog's size)
- 1x — **Dog Leash** (recommend two leashes for a large dog)
- 10x — **Small Screws** (10/24 x 3/4", or preferred size)
- 2x — **Large Screws** (10/24 x 3", for securing wheels on piece E)
- 12x — **Acorn Nuts**
- 1x — **Fleece** (or preferred padding material)
- 1x — **Gorilla Glue**

3. Tools

You'll need the following tools for this project:

- Screwdriver
- Scissors
- Measuring Tape
- Access to a 3D Printer (a Makerbot Replicator 2X was used for this project)
- Lighter
- Soldering Iron (optional)

4. Measuring Your Pet

In order to determine what size the wheelchair frame needs to be, you'll have to measure your pet properly. The diagram below visually depicts the three measurements that need to be taken. Measurement A is the width of your pet, measurement B is the height of your pet from the ground to the top of their shoulder bone, and measurement C is the length of your pet from their front belly back to their tail.

Once you have these measurements, you'll need to do a few simple calculations to determine the size of tubing that will be required for your FiGO wheelchair!

You will need:

- 2x tube measurement A plus 1"
- 2x tube measurement B minus the radius of your chosen wheel, then minus 1"
- 2x tube measurement C minus 2"

I have created a simple google spreadsheet that does these calculations for you as you input your dogs measurements. Click on 'File>save a copy' to edit the file for yourself.
https://docs.google.com/spreadsheets/d/1OUDnDBG-(so-nfdue-AFACkutDrCdGaDhrRI12huNscNe/edit?usp=sharing

Tags
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Print Thing Tag

- Measuring tape
- Access to a 3D Printer (a Makerbot Replicator 2X was used for this project)
- Lighter
- Soldering iron (optional)

4. Measuring Your Pet

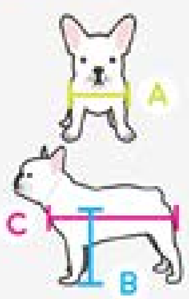
In order to determine what size the wheelchair frame needs to be, you'll have to measure your pet properly. The diagram below visually depicts the three measurements that need to be taken. Measurement A is the width of your pet, measurement B is the height of your pet from the ground to the top of their shoulder bone, and measurement C is the length of your pet from their front belly back to their tail.

Once you have these measurements, you'll need to do a few simple calculations to determine the size of tubing that will be required for your FIGO wheelchair!

You will need:

- 2x tube measurement A plus 1"
- 2x tube measurement B minus the radius of your chosen wheel, then minus 1"
- 2x tube measurement C minus 2"

I have created a simple google spreadsheet that does these calculations for you as you input your dogs measurements. Click on "file>save a copy" to edit the file for yourself.
https://docs.google.com/spreadsheets/d/1OUDn0DSQ-1zo-nfdue-AFACkzlDrC4GsDhRE2hxNeu/edit?usp=sharing

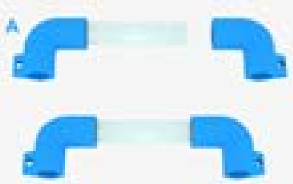


5. Instructions

Here's all you need to know about building your very own FIGO Wheelchair! First you need to gather all of the supplies, and 3D print all of the 10 joint pieces (A-E). Remember that the B piece needs to be printed mirrored as well (both files are provided in the files section).

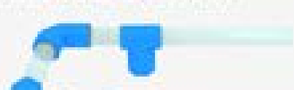
Afterwards, you're ready to start building the FIGO frame!

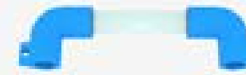
Step 1
First, take both of your A pieces and a width tube (measurement A), slide the tube into the first A piece, and then connect the second A piece to the tube. Make sure the tabs that will be used for the straps are facing in the direction pictured below.



Step 2
Next connect both A pieces to both length tubes (measurement C).

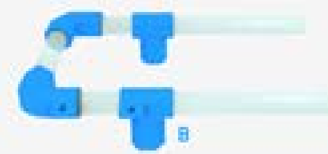
Step 3
Slide both B pieces down the length tubes leaving about an inch or so between B and A (this will change depending on your chair size, and you can easily move these pieces up later to match your pet's size). Make sure that the tabs on both pieces are facing outwards, and are both pointing to the back of the wheelchair (toward piece A).



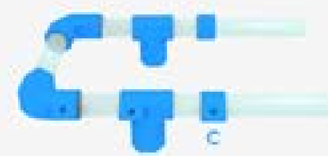


Step 2
Next connect both A pieces to both length tubes (measurement C).

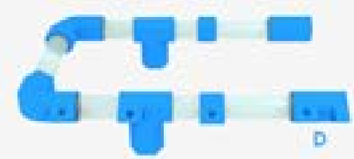
Step 3
Slide both B pieces down the length tubes leaving about an inch or so between B and A (this will change depending on your chair size, and you can easily move these pieces up later to match your pet's size). Make sure that the tabs on both pieces are facing outwards, and are both pointing to the back of the wheelchair (toward piece A).



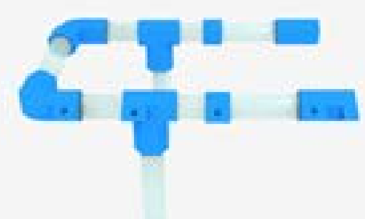
Step 4
Now do the same with both C pieces, remembering that the tabs are on the outside of the wheelchair.



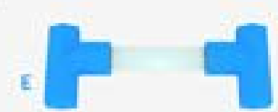
Step 5
Cap both D pieces on the ends of the length tubes, with the tabs facing outward.



Step 6
Now place both height tubes (measurement B) in both B pieces and then set your currently wheelchair frame aside.



Step 7
Now take both E pieces and one final width tube (measurement A) and connect them together. This step is not required for dogs smaller than 10 pounds. In this case, use piece E with no added support bar.



Step 8
Connect both E pieces to the height tubes you placed on your frame in step 6.

Step 7
Now take both E pieces and one final width tube (measurement A) and connect them together. This step is not required for dogs smaller than 10 pounds. In this case, use piece E with no added support bar.

Step 8
Connect both E pieces to the height tubes you placed on your frame in step 6.

Step 9
Add the wheels to both E pieces. Make sure you've added your bearings to your wheels if they don't already have them. Secure the wheels to the E piece with the longer 3" screw and cap it with an acorn nut. You may need to use a screw driver for this.

Step 10
Finally, add the straps to the chair. Both collars will be fastened to piece D at the front of the wheelchair, and the rest of the straps will be made out of a dog leash (or any piece of vinyl webbing that you may have). Piece A will require a longer strap as it is for the dog's legs. Pieces B and C's straps are for the dog's belly and will need to be the same size.

The dog collars can be cut in half, and then cut down shorter if need be. The fit will have to be very secure.

For the body straps (pieces B and C), place the leash around the dog when they are standing in the chair first to see how long it needs to be. For the leg strap, make it slightly longer than the belly strap length.

Cut the straps with scissors, and to prevent fraying quickly pass over it with a lighter. Once all of your straps are cut to size, cut two holes into them with scissors at each end, or use a soldering iron to burn a hole through. This is an especially useful tool as it will burn through the plastic preventing any fraying. The collar straps only need to be punctured at the ends that were cut.

Secure the straps to the tabs on each joint piece with the smaller screws and make sure they are tight!

Note: After the FIDO wheelchair is complete, the tube between the two A pieces, as well as the tubes connecting pieces B to E can be glued with Gorilla Glue to ensure stability of the chair. This is not as important when the dog is very light, but is recommended otherwise.

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6. Testimonials

Testimonials will be added very shortly!

7. Notes

It is important to note that you should consult with your vet if you have any questions or concerns with the fabrication or fit of the wheelchair. You may also use the comments of this project page to ask any questions.

All dogs will take time to get used to their wheelchair. Some adapt really quickly and some hate their chairs initially. It takes work to train a dog to be comfortable with their wheelchair.

I've worked with three dogs so far and I've experienced: a very comfortable and quickly adapted dog, an anxious and moody dog, and a timid pup. I've learned that leaving the chair in your living space and just letting your dog approach it and sniff it themselves helps!

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Secure the straps to the tabs on each joint piece with the smaller screws and make sure they are tight!

Note: After the FIGO wheelchair is complete, the tube between the two A pieces, as well as the tubes connecting pieces B to E can be glued with Gorilla Glue to ensure stability of the chair. This is not as important when the dog is very light, but is recommended otherwise.

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8. Update Log

March 2016: FIGO 2.0 Release

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