PARAMETRIC HABITAT: Virtual Catalog of Design Prototypes

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ABSTRACT

Generative tools contribute new possibilities to traditional design, yet formal representation of digital procedures can be counterintuitive to some makers. We envision the use of catalogues in parametric design, replacing abstract design procedures with a given set of visual options to select from and react to. We review the research challenges in realizing our catalog vision. We contribute an embryonic catalog generated from a formal list of parameters, demonstrated on a parametric mushroom. We also present a simple user study where students engaged in a design task relying on a catalog of prototypes generated by parametric design.

Author Keywords

Catalog; Generative Design; Parametric Design.

ACM Classification Keywords

H.5.2. User Interfaces: User-centered design.

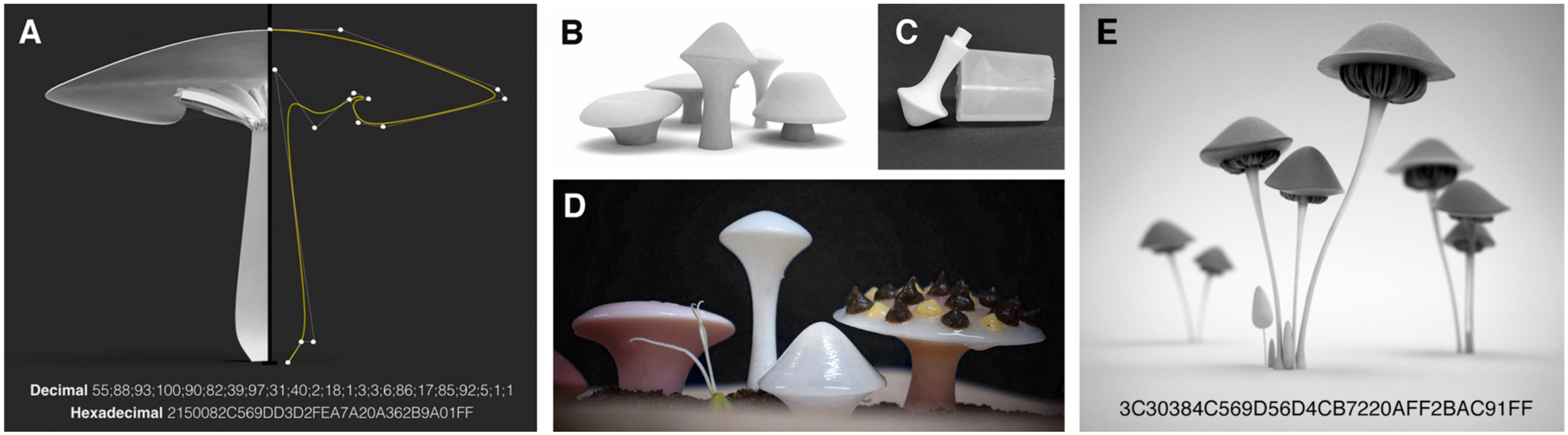

Figure 1: (A) Our parametric model of virtual mushrooms is constructed by revolving a parametric curve. A model ID number is generated using the control parameters. A demonstrated cooking application shows (B) five generated virtual mushrooms; (C) a silicon mold of one of these mushrooms; and (D) a dessert made with several of these molds. (E) Additionally, a concept design work (rendering).

INTRODUCTION

We are involved in selection tasks on a daily basis: whether we choose what to order from a menu; which shirt to buy in the store; or which music we would like to listen to while we drive. Additionally, our visual systems are adapted to recognize patterns and regularity in a noisy environment, probably as a result of long evolutionary survival: we easily detect ripe oranges on a tree, even if they are surrounded with many unripe, green ones; and we effortlessly detect mushrooms in a forest [1,22].

When we are engaged with a creative task, visual selection also plays an important role: it is part of a master's expertise. A sushi chef who goes to the market to choose the fresh fish of the day; a carpenter who carefully selects lumber for his or her work; or a designer who fits textiles to a sofa using a catalog—while they may use other senses later in the process, they all make their *initial* selections using their eyes.

Nonetheless, digital design favors other modes of work: parametric and generative designs, which are made by computers based on a formula or code. Computer-generated patterns controlled by a small set of inputs can demonstrate complex aesthetics [7,15,20]. However, as they rely on formal mathematical knowledge, these practices are not accessible to all designers [10,21], thus preventing many makers from exploring the new possibilities that digital practice holds. We believe that a virtual design catalog that samples the parametric space of design options and presents visual design prototypes can benefit computer-aided design (CAD) and facilitate the use of generative tools for a broad spectrum of designers.

Visual catalogs are ubiquitous in human-computer interaction, whether in retail environments; creative environments (such as Photoshop's brushes); gaming (such as choosing avatars); and more. In addition, HCI research has begun to explore the possibilities of virtual parametric catalogs.

One recent work, *Hybrid Practice in the Kalahari*, suggests that "in seeking ways to make digital tools that better facilitate exploratory modular practices, one approach is to design domain-specific CAD tools that enable designers to reconfigure {…} modular parts through a small number of operations" [10]. Later, Efrat et al. allowed makers to play with a limited set of digital meta-patterns in embroidery craft, using a catalog of pre-generated patterns, and suggesting that "the arrangement of parametric design [space] in modular representation… can assist makers unfamiliar with this practice" [5].

We present an *initial* process for constructing catalogs of parametric design models, highlighting guidelines for future catalog-based CAD environments. We start with a procedure for constructing a parametric space for an object, an important preliminary stage towards building a catalog. As a design-case, we build a catalog of parametric models that resemble mushrooms. A mushroom is a recognizable archetype, yet less culturally loaded than other organic archetypes such as flowers or leaves [2]. Additionally, we conducted a classroom study to evaluate the use of a catalog in a design task.

We include a contextual discourse on the potential role of catalog-aided model selection in virtual design environments. We rely on several design hypotheses, such as cataloging a small, sorted set of prototypes (fewer than seven), balanced by size variance. This digital catalog should allow for breeding, tweaking, and interpolating prototypes to generate new ones, thus allowing users fine control over the building blocks of their designs.

There are several technical, interactive, and cognitive challenges in properly constructing a catalog of design prototypes. We review and highlight the research challenges in formalizing a proper, minimally biased catalog construction paradigm. As most of these research challenges will require deeper investigation, we conclude this pictorial with a discussion of future work for research and investigations.

RELATED WORK

The discourse on creative processes has deep roots in academia, as scholars have long discussed the different creative paradigms people use when designing and building artifacts and images. Lévi-Strauss defined a *bricoleur* as "someone who […] does not subordinate each of [his means] to the availability of raw materials and tools conceived and procured for the purpose of the project… the rules of his game are always to make do with 'whatever is at hand'" [11]. Putting it simply, bricoleurs work with a given set of raw materials and tools, mastering the craft of manipulating them to their purposes. In addition, Papert emphasized the advantages of the improvised and intuitive practice of the bricoleur, especially when applied to education [6].

Within the design terrain, scholars have pointed to the restraints of computational practice in comparison to traditional craft [14]. Hence, in HCI and CG, researchers study territories that merge computational working paradigms using automation, and analytic and numerical processes, together with hands-on, intuitive and manual practices like traditional crafts, thus developing hybrid design territories [4,16,23,24,26].

We can roughly distinguish CAD practices as manual, freehand environments (such as NURBS work in Rhino); parametric dependencies environments (as in SolidWorks); or algorithmic design environments—generative design (as in [18])—where the computer generates the design solution autonomously.

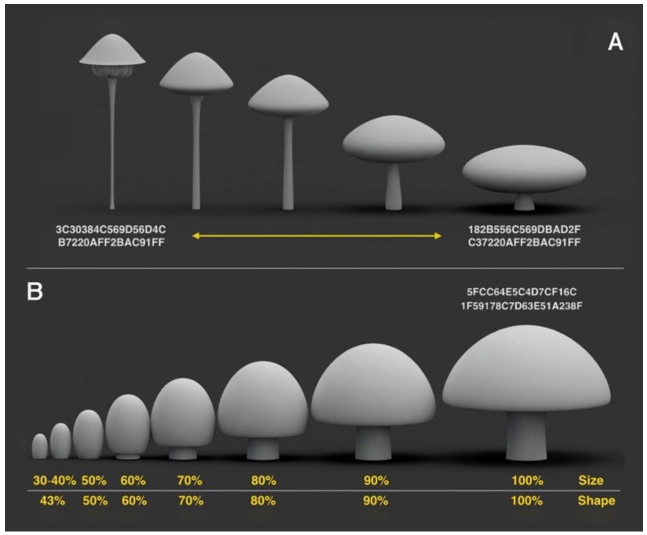

Figure 2: The parametric model of a virtual mushroom allows for (A) continuous transition from one model to another, and (B) application of a growth function to the mushroom models.

Researchers have strived to make digital design processes more intuitive, allowing for continuous and expressive modification of the virtual design [8,9,19].

Our work follows a different path, aiming to liberate parametric and generative design from formal analytic representation. We suggest an idea to create tools that facilitate exploratory modular practices using a design catalog of basic shapes. By applying a bricolage practice to CAD, we seek a procedure that manipulates parametric design in a tinkering manner. We contribute recommendations and highlight the challenges for discretization of a continuous parametric design, demonstrated on a design-case of a mushroom model.

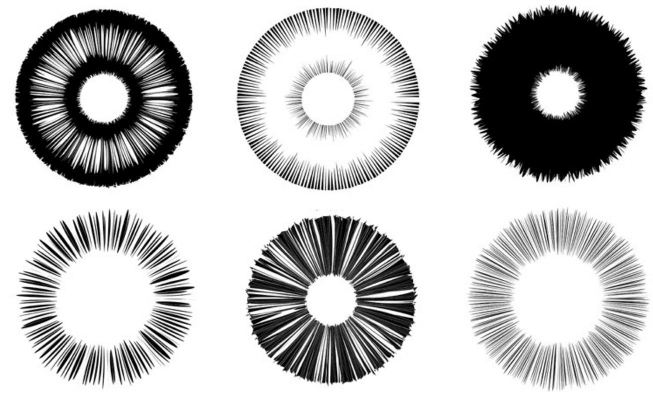

Figure 3: Digital spore prints: a signature of the mushroom gills' digital texture, resembling spore prints, which sometimes serve as an identification for the mushroom type.

THE PARAMETRIC DESIGN SPACE

Parametric design can be defined in a continuous or a discrete manner. We focus on continuous parameters and a representation of the design model that allows us to create a mathematical model. The model can span an infinite number of outputs, as the digital design tools have the advantage of a wide degree of freedom of movement in the continual space (see Fig. 2).

When the conditions and constraints of the main design task can be defined numerically, we can generate a solution automatically using an optimizing algorithm such as gradient descent (GD) or genetic algorithms (GA, see example in [28]). However, the conditions and constraints of the design problem can be hard to define, especially in terms of aesthetics and style, thus requiring manual involvement [25].

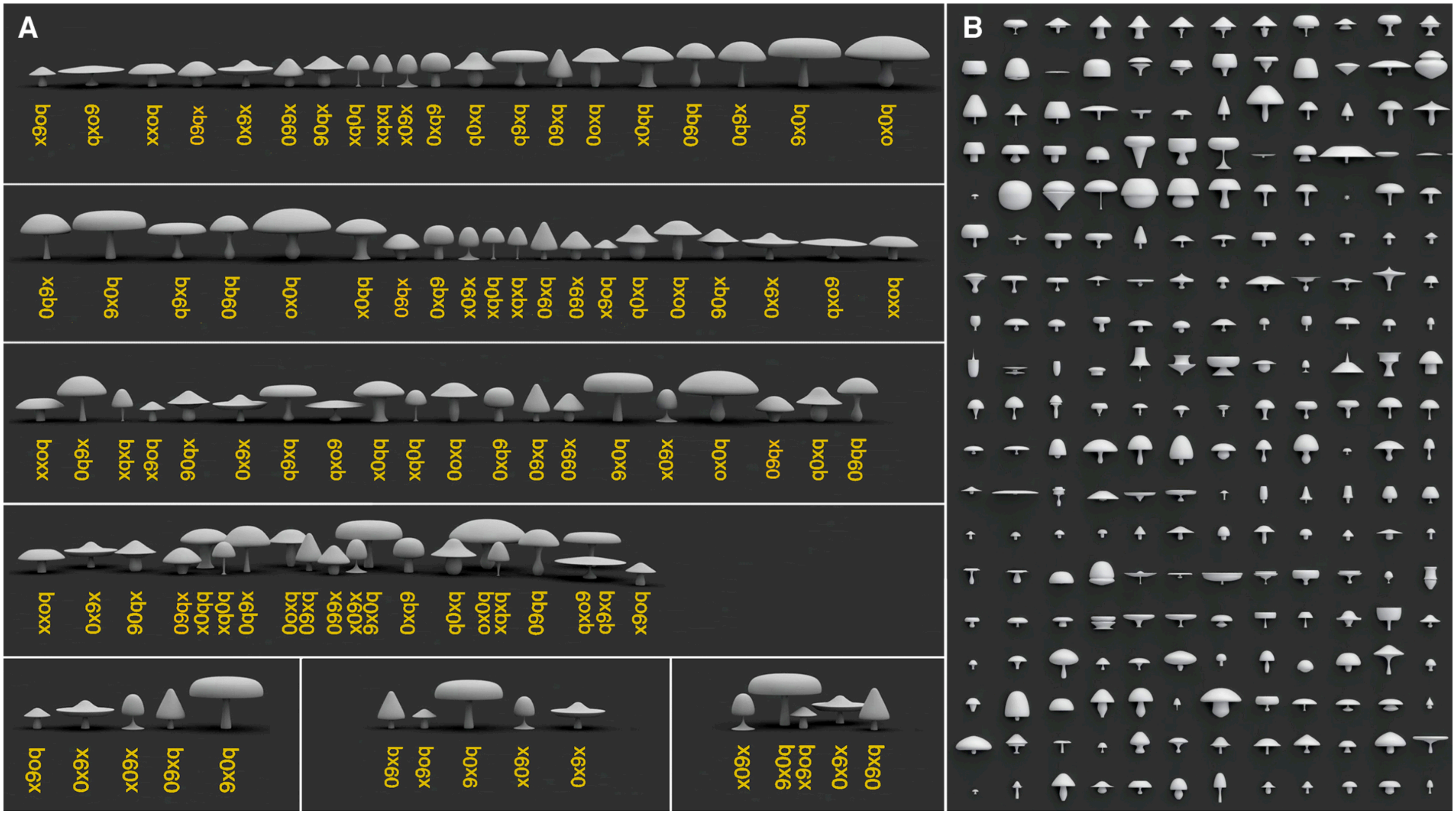

Figure 4: (A) Different horizontal ordering options for the mushroom prototypes. Twenty mushrooms ordered by: size, style, random, and natural; and five mushrooms ordered by size, random, and natural. How one can construct the least-biased order should be the topic of future research. (B) The mushrooms in (A) were selected from a table of mushrooms generated by 30 users. Here we present a portion of this table, where each line is a partial set of mushrooms selected by a single user.

To allow for an intuitive parametric design process, Efrat et al. suggests that the organization of parametric design in modular representation can ease makers into accessing the digital work progress [5]. This is because a catalog displays a finite set of options, as opposed to the infinite set enabled by the continuous space. Their user study indeed showed that the existence of a catalog eased access and evoked the users' interest in the novel technology. Yet, we wish to raise questions about methodology in order to construct a catalog of design prototypes, with the purpose of assisting in the generation of future parametric design catalogs.

Within the context of formal mathematical design, we aim to research an alternative to a paradigm based on analytic reduction. We define the modular representation of parametric design elements as digital building blocks, similar to physical building blocks and materials. We believe this strengthens the creator-creation bond, which cannot easily be reduced to a simply analytical model. We wish to ask how the order in which the elements appear influences the creator and what display types are recommended for various objectives. For example, how does a sculptor choose the right piece of wood for a new sculpture?

A PARAMETRIC MODEL OF AN OBJECT

Parametric design impacts many contemporary design disciplines. One of the major uses for parametric design is in pattern making, as computers can easily repeat basic elements to achieve complex sequences of symmetries [7,15,20]. Traditionally, ornaments and patterns rely on repetitive elements, such as geometric primitives (lines, circles, triangles) or more advanced figurative elements (leaves, flowers). Since basic geometric primitives are simple enough to be represented and manipulated without a catalog, we focus on the second group of figurative elements. Unlike flowers and leaves, which are archetypes widely used throughout the history of art in design [2], mushrooms are less common. Thus, mushroom shapes offer us a fresh approach to designing with a biological element, while still being familiar and widespread.

The mushroom family is structurally complex [3,12,13,17], encapsulating many fine differences, such as a varying range of cap shapes, stem shapes, cap margin shapes, sizes and proportions between the different parts of the mushroom, and other elements. Yet they have a unique, easily recognizable shape, and can thus be classified simply as "mushrooms," regardless of the viewer's pre-acquaintance with specific types.

Our work commenced with a study of the mushroom family itself as a case study; how they grow, their different features, what structural differences exist between them, and what parts all mushrooms share. We then turned to a structure-oriented study, where the mushrooms were deconstructed into different parts, and the wide range of possible shapes for each part was examined. Furthermore, we defined the minimal number of areas-of-interest needed to represent the widest range of mushroom parts, each parametrically described with control points on a revolved spline curve that assumed a symmetrical mushroom. After we had defined the different parts (mushroom's cap, gill, stem, etc., see Fig. 1A), we modeled a 3D mushroom using Rhino and its Grasshopper add-on (including the mushroom's growth, see Fig. 2). The model depends on defining a dozen anchor points in a XZY space, which serve as control points of a spline. The code and a detailed description of the model can be seen in the project site [http://amitz.co/catalog.html].

Figure 5: Three concept mushrooms made with our digital tool. Rendered using Octane Render and VRay.

BUILDING A CATALOG FOR A PARAMETRIC OBJECT: RESEARCH CHALLENGES

Here we list the main challenges of constructing a catalog of design primitives. We assume the family of figurative primitives the catalog is based on can be graphically distinguished. For example, various mushroom types share stylistic elements, assisting unified categorization, while a family of *animals* is significantly less uniform. Yet, this feature of virtual habitats depends on the specific design application, as well as the other families in use. We assume a catalog can include various families of shapes.

When choosing a family and developing the parametric model to represent it, we face three challenges: (1) how to choose the size of the finite set of prototypes to display; (2) how to extrude the most representative prototypes from the model; and (3) how to minimize the potential bias a certain display order may introduce to user selection, i.e. how to order the prototypes in the display. In Fig. 4A we present various orders in two set sizes (chosen randomly), selected from a bank of virtual mushrooms generated by 30 users (see Fig. 4B). We selected the prototypes in Fig. 4A by visual proximity of stylistic characteristics; future research will be required to define a technique that can span a wide space of design possibilities using minimal repetition.

USING A CATALOG IN A DESIGN TASK

Generally speaking, traditional parametric design relies on a formula or an algorithm to generate solutions that fit specific design requirements and conditions. The system receives input parameters from the user and generates a solution. Only *after* the generative process ends will the user be able to observe, analyze, and react to the visual output.

Conversely, when using a catalog of building blocks, the user tiles, assembles, and constructs an output using pre-selected design elements. This approach provides a perspective on some of the stylistic

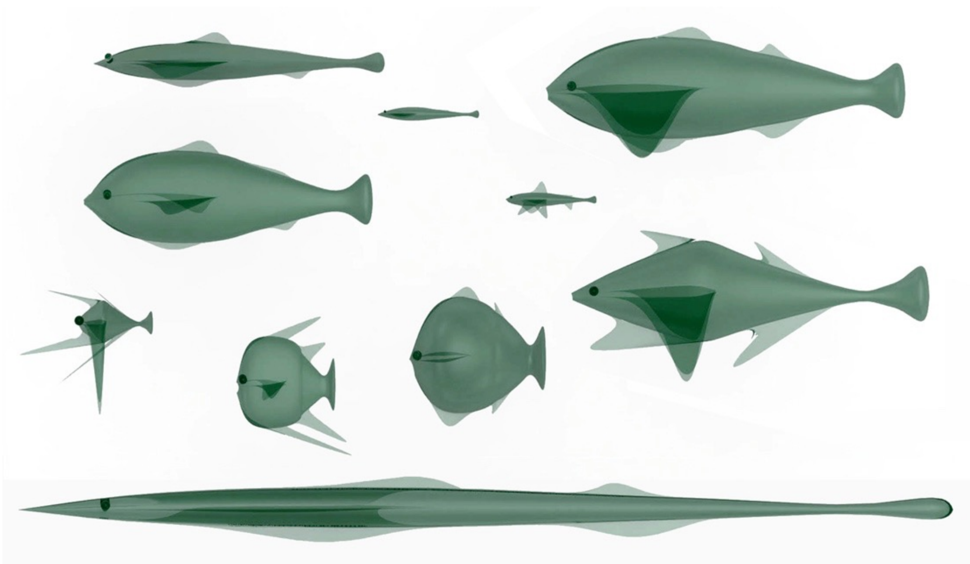

Figure 6: A set of virtual fishes generated from a parametric model. The model was developed by Raaz Herzberg.

characteristics of the output in advance and allows the user to react to the process in a way that resembles real-world design selections. While prior work has explored the use of a digital pattern catalog in textile craft [5], here we aim at using a catalog of design prototypes to act as *building blocks* for an *artifact*.

We evaluated our proposed design procedure in a classroom, by demonstrating the parametric design of our mushroom model to thirteen students in a Digital Design class at our university. All but two were computer science students (though they are all familiar with programming), and all but two also study design. As a class project, the students were asked (1) to create their own virtual catalog of approximately fifteen organic primitives (such as leaves, flowers, corals, fish, etc., with each student focusing on a single archetype), then share the catalogs with the other students; and (2) to create a virtual artifact (a fairy masquerade mask) by developing an automatic tiling program that uses visually selected elements from the catalogs the members created.

Catalog Building—Design by a Parametric Model

The catalog building assignment was defined as follows, and students were given three weeks to complete it:

Choose a family of natural shapes (such as flowers, butterflies, leaves, corals). Select three distinct examples from your family. Develop a parametric design space that contains your three examples and formally describes it. Building upon your parametric space, use Grasshopper to implement a parametric model of your design space. Your model must allow for continuous transitions between your three preliminary examples. Submit a table of ten to twenty models, including your preliminary examples and the transitions between them.

Students chose to work on seashells (two students); fish; leaves; flowers (five students); conifer cones; and beetles. Fig. 6 demonstrates one student's submission.

Generating a Fairy Masquerade Mask—Design By Selection from a Given Set of Preliminary Options

After the students finished and shared their catalogs, we continued to the second part of the project. We asked students to develop a digital process to tile user selections of design primitives, as requested below:

Choose a fairy reference and create a masquerade mask for it by implementing a 3D pattern using your selected primitives. Use Galapagos (a generative solver in Grasshopper) to solve an optimization problem—you need to define the design requirements of your pattern (such as giving a low score to patterns that position two elements from the same type next to each other;

or preferring certain types of symmetries, etc.). Generate three different masks.

Most student implemented solutions relying on no more than three different design catalogs, and using no more than three primitives from each one. The target functions defined by the students (as the subject of Galapagos optimization) are outside the scope of our discussion, as are the fairy references. In Fig. 7 we present three different masks generated by different students from five different catalogs.

Participant Surveys and Discussion

After completing the two parts of the project the students were asked to answer several questions regarding their experience. It is important to emphasize that all of the students participating in the class were familiar with computer programming and mathematics, and thus were not the optimal target group for our catalog concept. As we mentioned earlier, we hypothesize that catalogs can ease the implementation of parametric and generative design for designers who are *not* familiar with formal computational representation.

We asked the students to explain which of the methods they enjoyed more and had fewer technical difficulties with (*Design by a Parametric Model* and *Design By Selection from a Given Set of Preliminary Options*, named the *first method* and *the second method* correspondingly). We also asked the students to elaborate on whether they could compare one of the methods to other creative experience they are or were engaged with, and whether they had anything else to add to the discussion.

Eight students answered the survey, and seven of those preferred the first method. Students who preferred the first method reported that it allowed them to design unrestrictedly, as they were able to shape the parametric model as they wished. Using a catalog limits the set of options and does not allow for full creative expression. Several students claimed that they missed direct feedback in the second method—i.e., while we aim at allowing designers to react visually to building blocks, the generative procedure using Galapagos is slow and prevents direct manipulation of the design. Yet, the student who preferred the second method stated that while the first method allows for more direct intervention with the output, it is easier to achieve a complex model using the second method, as it merges in much more of the work that others have already done.

By comparison to other experiences, students noted that since it was a learning experience and some of the tools were not implemented in the most efficient way, they invested much more time in developing the tools than in actually designing with them. This is a significant bias in the experience that needs to be thoughtfully considered.

We need to be careful about drawing conclusions from this experience, as students were using both methods for the first time. Since we were in an educational setting rather than an experimental one, the tasks cannot be fairly compared, and the poll of participants does not represent the target group we intend to satisfy. Thus, instead of suggesting specific analyses regarding the comparison between the methods, we focus on points that represent strong indicators.

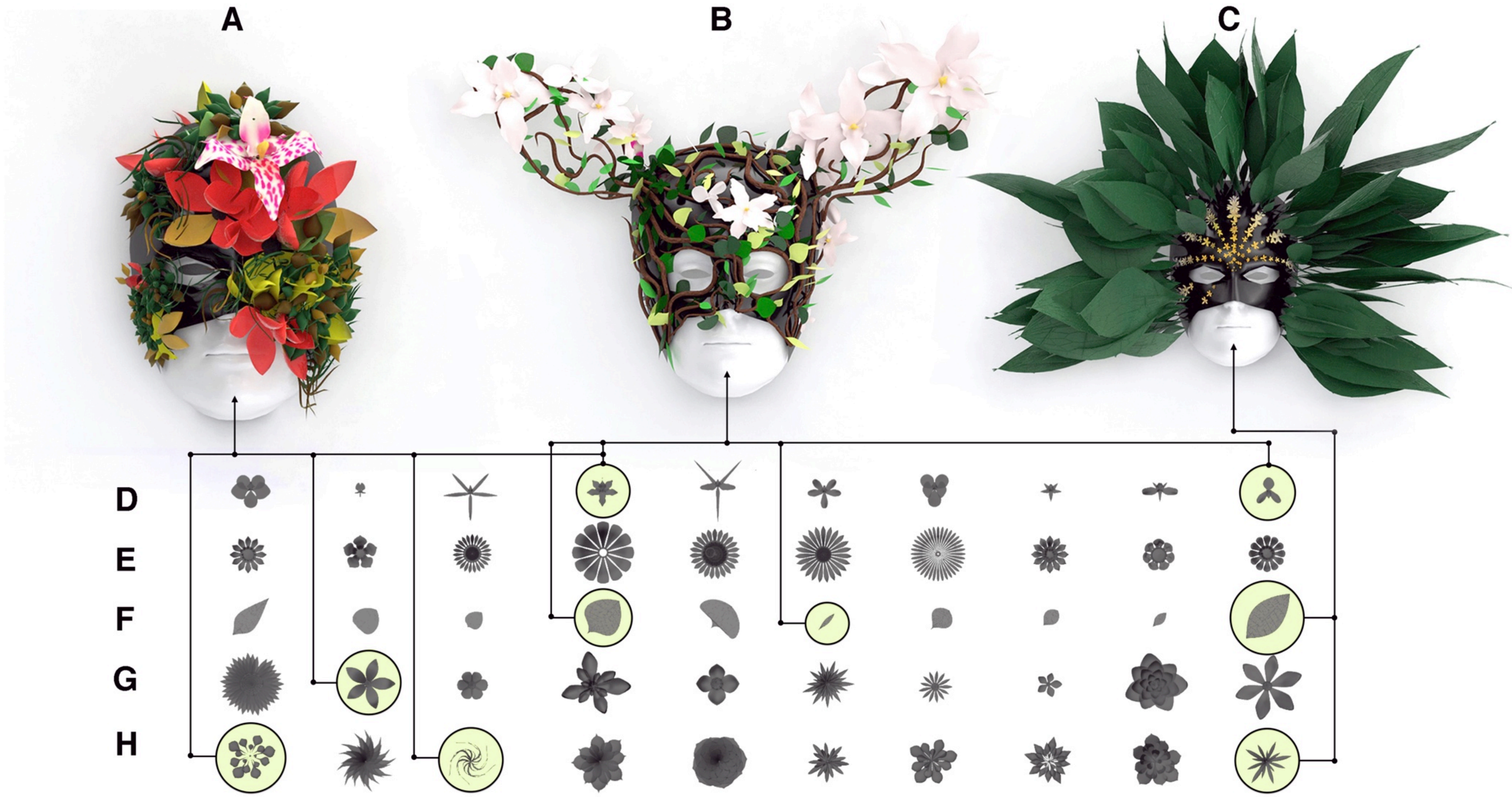

Figure 7: Three masks generated by tools students developed in class by tiling building blocks manually selected from catalogs of shapes according to specific optimization criteria. Mask credits: (A) Erez Levanon; (B) Naama Glauber; and (C) Adi Yehezkeli, made from catalogs developed by (D) Adi Yehezkeli; (E) Dafna Kaplan; (F) Matan Bar-Sela; (G) Tamar Levy; and (H) Naama Glauber.

Generally speaking, it seems that users missed the ability to tweak and fine-tune selections from a catalog in the second method. It will be important to include this option in future work, as it will probably increase users' satisfaction in their building-block selections.

CONCLUSIONS

Selection plays an important role in creative tasks. Based on related work and craft experience we hypothesize that the ability to visually select design resources is an important part of the human creative process. Yet, visual selection is currently not an important part of parametric and generative design. While this absence and the counterintuitive procedures of formal parametric design limit the creativity of some creators, they also call for access to user-friendly parametric design tools. We intend to further research the use of catalogs of design prototypes as building blocks for generative design procedures.

We demonstrate a method to make a catalog of design prototypes, with the aim of letting a user visually select preferred design resources and create a design by positioning them using generative or manual processes. This process resembles the use of raw materials in craft, such as selecting wood for carpentry or choosing flowers for an arrangement. To evaluate this concept, we choose to focus on generative pattern making. Due to its repetitive nature, parametric design is popular in producing patterns. Organic shapes are common in the history of pattern design; hence we chose to demonstrate our concept using an organic archetype, a mushroom, which is visually well-distinguished yet not used as often as flowers or leaves.

Moreover, we discuss the creation of generated virtual masks using catalogs of organic primitives such as flowers and leaves. These primitives were tiled algorithmically to create a pattern that covers a ready-made mask. We demonstrate applications for digital models of mushrooms, and show how a catalog can be used in a generative task of conceptual mask design.

We state assumptions and define challenges to overcome in future research on the way to extracting recommendations on the catalog-building process. The mask class assignment suggests that more work is needed to satisfy users' requirements for a catalog. Participants expressed a lack of satisfaction with a slow design process that relies on a static set.

We envision an interactive catalog, built around a set of prototypes for each archetypical object. The user should be able to generate more prototypes by breeding different ones, and should be able to tweak and fine-tune prototypes to allow for better design resolution. We hope that this will help to continue bridging analytic forms of creativity with an intuitive manner of artistic selection and expression to achieve a balanced hybrid design experience and results. With this vision in mind, additional research is required to realize the vision of interactive catalogs based on parametric and generative design CAD procedures:

- **Set sizes**—how the quantity of displayed elements affects the selection task.
- **Extracting typical prototypes from a model**—displaying the optimal range of options.
- **Order-based bias**—how to minimize selection bias originating in different display orders of the elements.
- **Tinkering with a prototype**—breeding and fine-tuning a custom object using two selected prototypes.
- **Interactive catalog**—creating a parametric object using an intuitive bricolage approach, with a catalog of parametric building blocks.

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REFERENCES
1. Rudolf Arnheim. 2004. *Art and Visual Perception: A Psychology of the Creative Eye*. (2nd. ed.) Oakland: University of California Press.
2. David Batterham. 2012. *The World of Ornament, Volumes 1 and 2*. Cologne: Taschen.
3. Ellen M. Dallas and Caroline A. Burgin. 1900. *Among the Mushrooms, A Guide For Beginners*. Philadelphia: Drexel Biddle. Retrieved March 26, 2018 from http://www.gutenberg.org/files/18452/18452-h/18452-h.htm.
4. Laura Devendorf and Kimiko Ryokai. 2015. Being the Machine: Reconfiguring Agency and Control in Hybrid Fabrication. In *Proceedings of the 33rd Annual ACM Conference on Human Factors in Computing Systems* (CHI ’15), 2477–2486. https://doi.org/10.1145/2702123.2702547.
5. Tamara Anna Efrat, Moran Mizrahi, and Amit Zoran. 2016. The Hybrid Bricolage: Bridging Parametric Design with Craft Through Algorithmic Modularity. In *Proceedings of the 2016 CHI Conference on Human Factors in Computing Systems* (CHI ’16), 5984–5995. https://doi.org/10.1145/2858036.2858441
6. Idit Harel and Seymour A. Papert. 1991. Situating Constructionism. In Constructionism: Research Reports and Essays, 1985-1990. Ablex Publishing, New York.
7. Wassim Jabi. 2013. *Parametric Design for Architecture*. London: Laurence King Publishing.
8. Jennifer Jacobs and Leah Buechley. 2013. Codeable Objects: Computational Design and Digital Fabrication for Novice Programmers. In Proceedings of the SIGCHI Conference on Human Factors in Computing Systems (CHI ’13), 1589–1598. https://doi.org/10.1145/2470654.2466211
9. Jennifer Jacobs, Mitchel Resnick, and Leah Buechley. Dresscode: supporting youth in computational design and making. In *Proceedings of Constructionism 2014 Conference*. Vienna, Austria.
10. Jennifer Jacobs and Amit Zoran. 2015. Hybrid Practice in the Kalahari: Design Collaboration Through Digital Tools and Hunter-Gatherer Craft. In *Proceedings of the 33rd Annual ACM Conference on Human Factors in Computing Systems* (CHI ’15), 619–628. https://doi.org/10.1145/2702123.2702362
11. Lévi-Strauss, Claude. 1966. *The Savage Mind*. Chicago: University of Chicago Pres.
12. Dalia Lewinsohn. 2015. Guide to Edible and Poisonous Mushrooms of Israel. 2008. Jerusalem: Carta.
13. Nina Lovering Marshall. 1901. *The Mushroom Book: A Popular Guide to the Identification and Study of Our Commoner Fungi, with Special Emphasis on the Edible Varieties*. New York : Doubleday, Page. Retrieved March 27, 2018 from http://archive.org/details/mushroombookpop00mar s
14. Malcolm McCullough. 1998. *Abstracting Craft: The Practiced Digital Hand*. Cambridge, MA: The MIT Press.

15. Tang Ming. 2014. *Parametric Building Design Using Autodesk Maya*. Abingdon: Routledge Publishing.
16. Moran Mizrahi, Amos Golan, Ariel Bezaleli Mizrahi, Rotem Gruber, Alexander Zoonder Lachnise, and Amit Zoran. 2016. Digital Gastronomy: Methods & Recipes for Hybrid Cooking. In *Proceedings of the 29th Annual Symposium on User Interface Software and Technology* (UIST ’16), 541–552. https://doi.org/10.1145/2984511.2984528
17. Roger Phillips. 2006. *Mushrooms*. London: Macmillan.
18. Arturo Tedeschi. 2014. *AAD: Algorithms-Aided Design. Parametric strategies using Grasshopper*. Brienza: Edizioni Le Penseur.
19. Cesar Torres and Eric Paulos. 2015. MetaMorphe: Designing Expressive 3D Models for Digital Fabrication. In *Proceedings of the 2015 ACM SIGCHI Conference on Creativity and Cognition* (C&C ’15), 73–82. https://doi.org/10.1145/2757226.2757235
20. Casey Reas, Chandler McWilliams, and LUST. 2010. *Form and Code: In Design, Art and Architecture, A Guide to Computational Aesthetics*. Princeton, NJ: Princeton Architectural Press.
21. Mitchel Resnick and Eric Rosenbaum. 2013. Designing for Tinkerability. In *Design, Make, Play: Growing the Next Generation of STEM Innovators*, Margaret Honey and David E. Kanter (eds.). Routledge, New York, NY.
22. Andrew P. Witkin and Jay M. Tenenbaum. 1983. On the Role of Structure in Vision. In *Human and Machine Vision*. Academic Press, 481–543. https://doi.org/10.1016/B978-0-12-084320-6.50022-0
23. Amit Zoran. 2013. Hybrid Basketry: Interweaving Digital Practice Within Contemporary Craft. In *ACM SIGGRAPH 2013 Art Gallery* (SIGGRAPH ’13), 324–331. https://doi.org/10.1145/2503649.2503651
24. 1.Amit Zoran. 2015. Hybrid Craft: Showcase of Physical and Digital Integration of Design and Craft Skills. In *ACM SIGGRAPH Art Gallery* (SIGGRAPH ’15), 384–398. https://doi.org/10.1145/2810185.2810187
25. Amit Zoran. 2016. A Manifest for Digital Imperfection. *XRDS* 22, 3: 22–27. https://doi.org/10.1145/2893491
26. Amit Zoran and Leah Buechley. 2012. Hybrid Reassemblage: An Exploration of Craft, Digital Fabrication and Artifact Uniqueness. *Leonardo* 46, 1: 4–10.
27. Amit Zoran and Dror Cohen. 2018. Digital Konditorei Programmable Taste Structures using a Modular Mold. In *Proceedings of the 36st Annual ACM Conference on Human Factors in Computing Systems* (CHI '18). ACM, New York, NY, USA.