DressCode: Tools and Activities to Engage Youth in Algorithmic Craft

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ABSTRACT

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INTRODUCTION
Computation is a driving force in our world. The recognition of the importance of computation to both national and international industry and advancement has resulted in the STEM Education Initiative, a national drive to engage young people in topics of math, science, engineering, and computer science [2]. Proposed K-12 computer science educational curriculums are aimed at teaching students the core components of computation and programing, as well as fostering sustained interest in a broad range of computer science professions [1]. These approaches explore digital applications of computer science that will appeal to young people, including game development, digital media manipulation, and web development. Parallel to the growth of youth STEM initiatives is the recognition of the educational potential of the Maker movement, which has produced a growing number of youth-oriented maker initiatives. These programs seek to create opportunities for young people to participate in hands-on learning through making [4], and conduct research on how hands-on-learning can be integrated with educational policy and practice [3]. Many youth maker initiatives are designed to connect directly to STEM educational objectives, by connecting making with principles in science, technology and math; however these initiatives also have great potential to connect with the arts. As researchers, we believe computation can serve as a powerful tool for creative disciplines. When applied to the arts, programming offers different paradigms for creation and new methods of problem solving. We see an opportunity to support young people in art-oriented programing by connecting computation to making. Specifically, we seek to support youth in the combined use of computational design and traditional arts and crafts for the production of functional and decorative physical artifacts. We use term *algorithmic craft* as a way of describing this collective practices.

Combining computational design and handcraft raises many interesting questions: What are the important design principles to consider when creating programming environments for physical design? How do we compellingly link textual code with visual designs, and what are the appropriate intersection points between textual manipulation and visual manipulation? What support is required to help people move back and forth from programming to building real objects in a way that is comfortable, expressive, and pleasurable? How can we remove the technical challenges involved in translating code into an object that can be successfully fabricated, but still support a wide variety of design styles, aesthetics, and approaches? Finally, how can we interlink the often disparate processes of physical prototyping with digital design and programming in a way that creatively reinforces both physical and virtual modes of working?

To explore these questions we developed a software tool called DressCode, to enable young novice programers to participate in computational design. We designed and implementation of a set of algorithmic craft activities in which high-school students used DressCode in conjunction with traditional forms of hand-craft to produce personal artifacts. Throughout our description and analysis of these experiences, we discuss design factors that enable young people to use computation in ways that emphasize pleasure, intellectual engagement, and utility in the service of personal expression.

ALGORITHMIC CRAFT
In order to illustrate the creative potential of algorithmic craft, it is useful to examine the key affordances of computational design and craft and how they can be combined into a single practice. In computational design, the abstract qualities of computer programming provide a powerful way of thinking about design. Similarly, computational design can be applied to any design domain, be it physical, visual, sonic, or interac-

tive. Our focus focus in computational design is the process of using computational processes to create visual forms and patterns. Although individual applications of computational design often consider material properties that are relevant to a specific domain, computational design does not possess an inherent connection to the material world. Craft on the other hand is closely linked to materiality. Craftspeople work in close contact with the physical world and craft artifacts and processes are directly informed by material properties.

Affordances of Computational Design

- **Precision:** Computation supports high levels of numerical precision.
- **Visual Complexity:** Computational design allows for the creation and transformation of complex patterns and structures through rapid automation and iteration which allows for the combination and manipulation of large numbers of simple elements in a structured manner.
- **Generativity and Self-Similar Forms** Computation allows for the programmer to create algorithms that allow for the computer to autonomously produce unique and unexpected designs.
- **Parameterization:** Computation allows users to specify a set of degrees of freedom and constraints of a model and then adjust the values of the degrees of freedom while maintaining the constraints of the original model.
- **Documentation and remixing:** Computationally generated designs are generated by a program which can be modified by other designers, and serve as a form of documentation of the design process.

Computational design also contains a number of unique challenges:

- **Formalizing complex problems** As design problems grow in complexity, formalizing the problem in a manner that can be expressed programmatically becomes challenging.
- **Creating singularities:** A designer will often choose to deviate from a set pattern or structure at specific points in order to create a special emphasis in the area of deviation. Because computational design is governed by a systematized ruleset, the methods of breaking these rules at arbitrary points are often unclear or tedious to implement.
- **Selecting a final design:** Computational design gives the designer the ability to produce extremely large numbers of solutions to a single design problem. While this is useful in situations where multiple solutions are required, when a single design must be chosen, the process of deciding on a solution is difficult, especially if the decision is based on aesthetic criteria.

Affordances of Craft

The cultural connotations of craft have varied throughout history, however forms of craft have endured, both as a recreational pursuit, and as set of valued artisanal practices. Below we describe the specific aspects that are integral to algorithmic craft.

- **Materiality:** Craft involves the manipulation of physical materials by hand, which is often an intuitive physical process. The decisions made in the craft process are altered by the feel of working with the material.
- **Pleasure:** Fundamental to traditional conceptions of arts and crafts is the idea of pleasure in working with one's hands [5]. This emphasis on pleasure is retained in conceptions of professional and amateur craft practices today.
- **Unification of form and function:** Although not all craft is functional, many forms of traditional craft can applied the creation of useful objects. In addition craft often emphasizes the importance of beauty in the form and ornamentation of objects. Well crafted artifacts frequently demonstrate the successful unification of aesthetics and utility.
- **Craftsmanship:** Put in a description of craftsmanship

The potential of Algorithmic Craft

The combination of computational design and craft offers the opportunity to produce pieces that are connected to a distinct space, time and process, and that are primitived by material properties, while incorporating patterns and forms made possible through computational processes.Objects that emerge from a combined practice of digital fabrication and craft are often characterized by their physical craftsmanship, technical mastery, and exceptional aesthetic. Practitioners in this space blur the boundaries between engineer, designer, and artisan. One of the advantages of merging craft and digital fabrication is that it ensures that machine-produced artifacts retain their personal history. Combining computational design and craft also offers the opportunity to engage people with interest in craft in the use of computational tools.

Digital to Physical Translation

In order to connect the digital artifacts of computational design with the physical world of craft, some form of transition is needed between the digital and the physical. Digital fabrication technology provides one method of connecting the abstraction of computational design and the material domain of craft by converting digital designs to physical forms. Digital fabrication technology ranges from the additive processes of 3D printing, to the subtractive manufacturing techniques of laser cutting, CNC mlling and vinyl cutters. Subtractive fabrication technology often corresponds well with craft processes Unlike most 3D printing technology, subtractive processes can work with a wide range of materials [**?**].

Time is an important quality of crafting. Handcrafted artifacts often require a great deal of time to complete and involve repetitive tasks. Because the process of crafting is often pleasurable and contemplative, many people look forward to spending time productively engaged with their hands. In algorithmic craft, the role of digital fabrication is not to speed up craft, but to facilitate the translation of computational forms to physical materials. These physical forms, in turn, can be primitived through craft processes, and imbue computational designs with individuality, utility, and temporality. Several forms of digital fabrication machines are capable of producing forms that are suitable for both expert and novice levels of handcraft. Because subtractive fabrication technologies work with materials like wood, paper, and fabric, they support the creation of objects that are readily primitived by the human hand. Laser-cut parts can be sanded, polished, painted, sewn, or folded after they emerge from the machine. Vinyl cutters also can be used on cloth and paper. They also produce patterns in adhesive vinyl that can be applied to screens for for screen printing. Laser cutters and vinyl cutters also fabricate at a faster rate than 3D printers or milling machines, and permit a higher tolerance for error during the craft process because it is feasible to re-cut damaged parts. Inkjet printers can also function as a form of digital fabrication, as they can print on cloth, or transparencies used in screen printing...

Challenges in access and application

primary barriers being: perceptual: people don't know you can use programing for physical making and craft intellectual: learning the unique affordances of computation and applying them in personally meaningful ways technical- challenge of using programing for design Focused on software design for the technical, activity design for the perceptual

RELATED SOFTWARE TOOLS

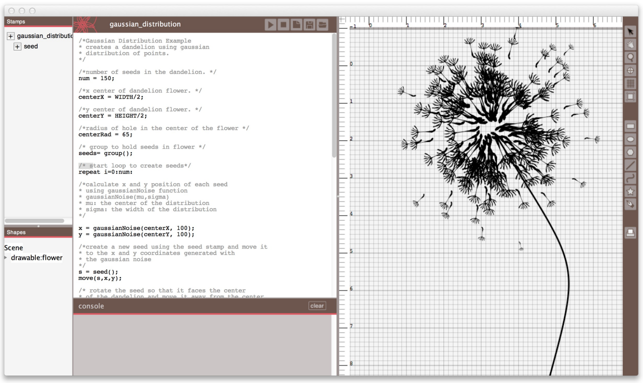
Professional Tools

Entry-level Programming Environments

Entry-level CAD Tools

DRESSCODE SOFTWARE DESIGN

DressCode is a 2D computational design tool aimed at novice programers. The primary objectives in the design of DressCode were to reduce the technical challenges of computational design, to foster independent and deliberate design decisions, and to assist in the creation of designs that were viable for craft applications. Although the name of the tool reflects an emphasis on wearables and fashion, as an application DressCode is general purpose, and can be applied to many forms of algorithmic craft. The software is comprised of the following elements: A custom programing language and drawing application programing interface (API), an integrated development environment, and a graphic user interface design tool.



```
/*Gaussian Distribution Example
* creates a dandelion using gaussian
* distribution of points.
*/

/*number of seeds in the dandelion. */
num = 150;

/*x center of dandelion flower. */
centerX = WIDTH/2;

/*y center of dandelion flower. */
centerY = HEIGHT/2;

/*radius of hole in the center of the flower */
centerRad = 65;

/* group to hold seeds in flower */
seeds= group();

/* start loop to create seeds*/
repeat i=0:num:

/*calculate x and y position of each seed
* using gaussianNoise function
* gaussianNoise(mu,sigma)
* mu: the center of the distribution
* sigma: the width of the distribution
*/

x = gaussianNoise(centerX, 100);
y = gaussianNoise(centerY, 100);

/*create a new seed using the seed stamp and move it
* to the x and y coordinates generated with
* the gaussian noise
*/
s = seed();
move(s,x,y);

/* rotate the seed so that it faces the center
```

Figure 1. The DressCode software

Interface

The interface of DressCode is divided into two sections: a design panel on the left and a coding panel on the right. The design panel approximates many of the features of a digital graphic design tool, with rulers, a grid, a drawing board, and a graphic tool menu. The drawing board defines the coordinate system referenced by the drawing API with the upper left hand corner corresponding to (0,0) in cartesian coordinates. Users can resize the drawing board and set the units to inches or millimeters at any point during the design process by selecting the drawing board icon in the tool menu. Similarly, the pan and zoom tools allow the user to navigate around the drawing board. The print tool opens a dialog that allows the user to export their current design in a vector format for output through digital fabrication.

The coding panel contains a primary window for entering text, and an output console for print output and error reporting. It also contains two additional panels, a declarative listing view, and the Stamp menu. Both of these panels are discussed in detail in the Graphic Tools section. A toolbar on top of the coding panel allows the user to save their existing program, open a program, or run their current program. When a program is run, the resulting design is displayed in the design panel. The DressCode programming language is interpreted with semantic functionality that is simulated through a Java-based library. For most programs, the interpretation process is instantaneous; however, some programs with complex operations require several seconds to be executed. Early in the development process, we experimented with automatic interpretation, wherein the design would be automatically updated as changes were made to the code. Early user testing demonstrated that this process produced a great deal of frustration, and people explicitly requested control over running their program and updating their design.

Programming Language and Drawing API

DressCode features a custom textual programing language with native 2D drawing functionality[1]. The language supports conventional datatypes including numbers, strings, booleans, and lists, and also supports drawing primitive datatypes such as ellipses, rectangles and polygons, as well as groups of primitives. The language also contains support for basic expressions, as well as conditionals, loops and user-defined functions. DressCode is dynamically typed in order to reduce syntactic challenges for people new to textual programing. DressCode determines how to treat the data assigned to an identifier based on context and identifiers can be assigned to datatypes that differ from their original assignment at any point.

The DressCode drawing API is s formulated on an Object Oriented Programming (OOP) paradigm which enables users to create and manipulate collections of geometric primitives including points, lines, curves, polygons, ellipses, rectangles

[1]A full specification of the DressCode language and API is available at: **http://jacobsj.scripts.mit.edu/dresscode/index.php?title=Drawing_API_Reference**

```
//repeat statement
repeat i=0:10:
ellipse(0,i*10,10,10); //draws a vertical row of 10
     ellipses
end
```

and imported SVG primitives. Shape primitives are initialized by calling the appropriate primitive method, and passing it a set of parameters designating the initial appearance of the primitive. For all primitives besides lines and curves, the first two parameters designate the coordinates of origin point of the primitive, and each primitive is drawn in the design panel relative to this central origin point. There is no "draw" method for DressCode. Instead all primitives are automatically drawn in the order of their initialization. This was designed to make it as easy and immediate as possible to have a design appear on the screen. Objects can be selectively hidden with the hide method.

All primitives in DressCode can be modified through two kinds transformation methods, Geometric and Stylistic. Geometric transformations allow for primitives to be rotated, scaled or moved or combined with other primitives. All geometric transformations are performed relative to the origin of the primitive, unless otherwise specified. Rotation statements for example have an optional third parameter which specifies a point to rotate the primitive around. Stylistic transformations affect the appearance of a primitive, and can modify properties like fill and stroke color, stroke weight, and presence or absence of fill and stroke. Transformations on a primitive are performed by assigning an identifier to the primitive, and then calling the transformation method with the identifier. By using the transformation methods to manipulate primitives in a structured manner, it is possible to generate complex and interesting designs from simple forms. Through these methods, DressCode was intended to support the affordances of computational design, specifically precision, visual complexity, generativity and stylistic abstraction, in a way that was feasible for new practitioners.

As mentioned, DressCode also contains a set of transformation methods that allow primitive primitives to be combined with one-another via polygon boolean operations. Polygon booleans are widely used in CAD applications and are essential for many forms of digital fabrication because they allow for complex configurations of primitives to be combined into effective toolpaths. DressCode contains methods for performing unions, intersections, differences and either-or intersections between any two or more primitives. They can also expand strokes to filled polygon paths, enabling the translation of line art to a form that will maintain its appearance when fabricated. By positioning these operations as primary components of the DressCode, we attempted to create a programming language that produced forms that were applicable to fabrication as a direct result of the design process.

As a method of organizing sets of primitives, DressCode contains a group datatype, which essentially is a specialized list for primitives. Groups can be initialized with a starting set of child primitives, or they can be initialized as empty, and then later have primitives added (or removed), from them. Groups automatically maintain an origin that is the average of all their children's origins. Geometric transformations performed on groups will relatively effect all of the primitives within the group; for example, if a group of polygons is moved to 0,0, then the origin of the group will become 0,0, with all polygons in the group being drawn relative to that new origin point. Groups can be multi-dimensional, and contain other groups. Stylistic transformations applied to groups will also be applied to each child. Groups also facilitate more advanced transformations. For example, it is possible to clip a group of primitives within the bounds of a single primitive to serve as a form of clipping mask, and a union can automatically be performed on all objects in a group with the merge method.

We chose to create a textual programing language for DressCode because we believe textual programing is well suited to transparent representations of computational design algorithms. In recognition of the challenges of first-time text programming, we also focused on creating intuitive forms of interaction and feedback to correspond with the DressCode language. These are inherent in the graphic drawing tools, which we discuss in the next section.

Graphic Tools, Organizational Structures, and Visual Feedback Mechanisms

The drawing and manipulation tools in DressCode are designed to allow users to create and modify elements of their design through graphic selection. Collectively, the drawing functionality of the tools is similar to the functionality of many existing forms of 2D vector graphics software. The tools are distinguished from other graphics software tools because they maintain a direct symmetry with the DressCode programming language. Each tool correspond directly to a method in the drawing API. More importantly, the use of each tool automatically generates a corresponding textual statement in a user's program. This enables elements that are created graphically, to be immediately manipulated through textual programing, and is designed to encourage a natural flow between graphic drawing and textual programing throughout the design process. The toolset includes regular primitive creation tools (ellipse, rectangle, polygon, line curve), and an svg import tool. There is also a pen tool that allows for the creation of irregular forms. Use of the pen tool generates a list of points in the text program, and statement initializing a polygon with the list. Because of the symmetry between the DressCode graphic tools and the DressCode language, there is no functionality hidden from the user in the process of modifying elements graphically. The program that results from a graphically modified design is human readable, and can be frictionlessly shared with other users, or copied and pasted into other DressCode programs.

(figure:2). In addition to the primitive generation tools, there is also a selection tool, which allows for individual primitives and groups to be manually selected with the cursor, and moved to different points on the drawing board. When a primitive is moved for the first time, a textual move statement is inserted into the user's program, with the identifier for the moved primitive as the first argument. If the moved primitive does not have an identifier, the primitive declaration is wrapped by a move statement. For all subsequent moves of that primitive with the move tool, the inserted move statement is updated to reflect the new coordinates of the primitive.

Figure 2. Graphically created polygon, rectangle, and irregular polygon, and corresponding automatically-generated code. The irregular polygon has just been moved with the selection tool.

It is also possible to select primitives in the declarative view panel. The declarative view contains a listing of all primitives in the current design, listed by their type (polygon, line, ellipse etc.) and identifier. Child primitives of groups are shown as nested elements below the group. When a primitive is selected in the declarative view, the primitive is simultaneously selected (and highlighted) in the design view, and the line where the primitive was last modified in the textual program is highlighted (figure:**??**). This declarative view functionality is designed to provide visual feedback on how elements of a design connect to the a user's program, and provide a practical selection technique for selecting and modifying individual children within a complex group.

Figure 3. Declarative view with selected primitive

Finally, DressCode contains functionality to help people organize their code in the form of *stamps*: auto-generated functions that return shape primitives. Two forms of stamps can be created: dynamic and static. Dynamic stamps are created by selecting a portion of code in a user's program. and then selecting the "create stamp from selected code" option from the menu. A dynamic stamp will package the selected code in a function with a name specified by the user, and automatically return any primitives that are generated by the selected code in the last line of the function. Static stamps are created by graphically selecting a primitive or group of primitives with either the selection tool or the declarative view, and selecting the "create static stamp from selected objects" option. Similar to dynamic stamps, static stamps are a function with a user-defined name that return a copy of the primitive or group that is selected. Static stamps differ in that they contain an explicit representation of the selected primitives. Static stamps were created to assist in the process of generative design. For example, if you create a random collection of shapes using a random or noise method, the next time the program is run, a different random collection will be generated. If a user wishes to maintain a specific instance of a generative design, they can create a static stamp from it, which will contain methods describing that discreet representation of shapes. Stamps are listed the stamp menu and can be added to a user's primary program by selecting the "+" icon next to each stamp. The functionality of both static and dynamic stamps can be modified by the user, by selecting the stamp from the menu, which will display the stamp code in the primary code window in an editable format.

ACTIVITY DESIGN

Domain-specific software is an important component of engaging youth in algorithmic craft; however it is equally important to appropriately design the context in which the software is applied. In this section, we discuss the primary components of our activity design, for which DressCode was the primary design tool. Because algorithmic craft combines aspects of computation, design and craft, we focused on an activity structure that would emphasize key components from each of these domains through three forms: learning, creation and reflection.

Learning

Instruction in our algorithmic craft activities was divided between imparting conceptual understanding of the creative opportunities of algorithmic craft, and teaching practical skills necessary to act upon this knowledge. We presented participants with a conceptual overview of the core principles described in the Algorithmic Craft section, by sharing examples of professional projects that demonstrated these properties. We made a particular effort to link the properties of computational design to more familiar contexts, for example comparing parameterization to the process of creating a size-variable dress pattern for sewing, or using a coin flipping and drawing activity to demonstrate the properties of randomness and generativity. To provide participants with the required technical knowledge for computational design, we conducted guided activities in programing in DressCode. For the programing lessons, we limited instruction to a specific design principle, such as radial symmetry or a random walk, and assisted participants through the process of creating their own algorithms that expressed this principle. For the craft skills, the instructors demonstrated the basic techniques of the craft activity, such as how to pull ink through a screen for screen printing, or how to set snaps into leather, and then gave participants the opportunity to try the process themselves.

Creation

Because one of the primary objectives for algorithmic craft activities is to have participants emerge with a completed artifact, we devoted the majority of activities to time for the participants to develop their designs and projects. Following each learning portion, we provided participants with time to experiment with the concepts or techniques that were covered, and develop their own interpretations. We also conducted longer-term design sessions that lasted 1-3 hours each and gave participants the opportunity for open-ended computational design. These sessions were supplemented by providing participants with DressCode examples which they could reference, modify or remix, quick syntax-reference sheets and an online code reference. Instructors were also present to help with programing questions, or offer design suggestions. The physical craft materials were made available to participants during the computational design sessions, so they could take their properties into account as they created their design.

Materials

Reflection

Critiques

USER STUDIES

Preliminary Study (Bracelets)

Bracelet Results

Primary Study (Screen Printing)

Screen Printing Results

ANALYSIS AND DISCUSSION

Generative Design Practices for Physical Objects

Discuss success / challenges of Stamp tool, GUI drawing and transformation tools
Embracing of Benefits of Computational Design by practitioners
Emergence of narrative in random structures

Forms of knowledge Sharing in Algorithmic Fabrications

Levels of design- tinkering with examples to building from scratch
Sharing code and sharing craft artifacts
Teaching physical techniques
Blurring the boundaries between technical programing advice and objective design criticism.

Physical and Digital Notions of Value

Conceptions of Difficulty
Digital and Physical Craftsmanship
diversity of experience (things people found to be difficult vs enjoyable)
Added value of code-derived artifact.
Added value as the result of physical labor.

Personal and Cultural Relevance in Algorithmic Craft

Aesthetics- enabled through code and graphic manipulation
cultural appropriateness of aesthetics (gender, youth)
Utility- changes in understanding of applications of programming, design. Material importance

Opportunities in Craft and Code Hybridization

Digital Feedback mechanisms vs social feedback mechanisms (critique)
Starting with craft- Desire for enhanced drawing functionality
Open question of what the resultant product is. (screen? artifact? program?)

RECOMMENDATIONS FOR FUTURE DESIGN

Transparency

- **Tools should support design techniques that demonstrate the benefits of computational design.**
- **The software interface should prioritize interaction through programming.**
- **Programming languages should have a design-oriented programming syntax, developed with novice programmers in mind.**

Literacy

- **Tools should reduce the technical challenges of fabrication.**
- **Tools should be supported through fabrication and craft-specific documentation.**
- **Activities should encourage discussion and group critiques of work, and when possible, use in-person facilitation and guidance.**

Flexibility

- **Activities should blend domain specificity with creative openness.**
- **Software tools should be free and open-source.**

Specificity

- **Materials matter.**
- **Select approaches with Craft and Computational Resonance**
- **Consider the cultural implications of algorithmic craft experiences.**

CONCLUSION

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