Paper Modelling from a Distance: Computational Crafts on the Web

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Abstract: Much of the rhetoric surrounding the World Wide Web celebrates the advantages of the "virtual" (and by implication, immaterial) world. In contrast, we see the Web as potentially enhancing the practice of handicrafts. This paper reports on recent developments in implementing a "Platonic Solids Applet" in Java to permit students to select and decorate folding nets for polyhedral solids made from paper. We describe both the applet and the original paper-sculpture design application, *HyperGami*, to which it is related; we describe ongoing work toward creating a mathematical children's book integrated with Web-based elements; and we discuss the strengths and limitations of the Web in the practice of handicrafts.

I. Introduction

Much of the current rhetoric surrounding the burgeoning popularity of the World Wide Web emphasizes the Web as an emblem of "virtuality." In this vision, the primary advantage of the Web lies in its ability to allow human beings to transcend the limitations of time, space, the body, and the physical world generally. Those interested in art and science may visit virtual galleries and museums; students may attend virtual classrooms; experiments may be performed in virtual science laboratories; social structures are developed and cultivated within virtual communities and "worlds." In every case, the implicit assumption is that the conditions of physical embodiment—in actual laboratories, classrooms, museums, bodies—collectively represent a barrier or expense to be overcome by a more efficient culture of incorporeality.

Eloquent statements on behalf of this vision of technology are not hard to find. In Nicholas Negroponte's book *Being Digital*, he writes, "In the same ways that hypertext removes the limitations of the printed page, the post-information age will remove the limitations of geography. Digital living will include less and less dependence upon being in a specific place at a specific time...." [Negroponte 1995] A similar theme of unlimited possibility and abundance is invoked by Michael Benedikt in his introduction to *Cyberspace*, a collection of essays on virtual worlds: "Cyberspace: Through its myriad, unblinking video eyes, distant places and faces, real and unreal, actual or long gone, can be summoned to presence.... Around every participant, this: a laboratory, an instrumented bridge; taking no space, a home presiding over a world... and a dog under the table." [Benedikt 1991] Sherry Turkle, in her thoughtful (and often cautionary) book *Life on the Screen*, describes a world in which constructs such as friendship, love, and personality undergo a metamorphosis under the influence of computer-based telecommunications: "In the story of constructing identity in the culture of simulation, experiences on the Internet figure prominently, but these experiences can only be understood as part of a larger cultural context. That context is the story of eroding boundaries between the real and the virtual, the animate and the inanimate, the unitary and the multiple self...." [Turkle 1995]

Compelling as these visions are, we do not believe that they need represent a monolithic view of the purpose and meaning of technology generally—or of the World Wide Web in particular. Our own interests lie in the integration of computational media and handicrafts—that is, in the use of computers (and communications) to enrich and rethink traditional creative activities rather than to render them obsolete. In pursuing this line of thought we have developed an educational application named *HyperGami* [Eisenberg & Nishioka 1997], which may be thought of as a design environment for polyhedral paper models and sculptures. Polyhedral modelling is of course a venerable craft activity in mathematics education [Mühlhausen 1993, Pedersen 1988]; but the goal of HyperGami is to move beyond the traditional boundaries of that activity, and to extend its creative potential by permitting students (as well as professional mathematicians and designers) to create polyhedral models whose levels of complexity and aesthetic appeal would have been unachievable in the absence of computers.

This paper reports on recent developments in making HyperGami constructions and activities available over the World Wide Web. The Platonic Solids Applet is a newly-developed Java program that allows students to create decorated paper models of (HyperGami-designed) polyhedra. Though still in a relatively early stage of development, the Platonic Solids Applet points the way toward more powerful tools for paper sculpture (and for mathematical craftwork) over the Web.

The following section of the paper will describe the current implementation of the Platonic Solids Applet, and its relationship to the larger HyperGami system from which it is derived. The third section will describe a broader project for which our Platonic Solids Applet represents an initial step: namely, the design of a mathematical children's book to be combined with interactive elements and tools available over the Web. The final (fourth) section will describe ongoing work in the HyperGami project with emphasis on the ways in which computational crafts may (or, importantly, may not) ultimately be enhanced by the capabilities of the Web.

II. The Platonic Solids Applet: an Overview

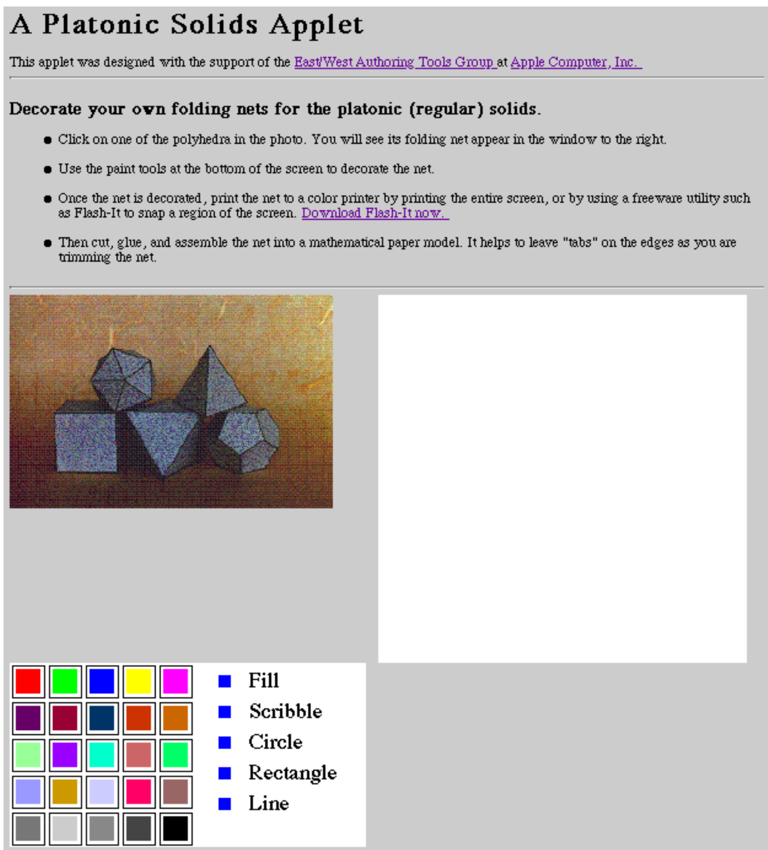

Figure 1: A screen view of the Platonic Solids Applet.

The Platonic Solids Applet is a Java applet[1] that permits users to create decorated paper models of the five regular, or Platonic solids (i.e., those solids consisting entirely of regular polygons as faces, and for which

[1] The Platonic Solids Applet was written in Java and created using both the Roaster Integrated Development Environment (Natural Intelligence, Inc., Cambridge, MA) and the Sun Java Developer's Kit

each vertex is included in the same number of faces). The essential idea of the applet is that the user may select a polyhedral object depicted in a photograph; the program then supplies the user with a "folding net" for that object (a two-dimensional pattern that can be folded into the desired solid). This folding net may be decorated by the user, after which it may be output to a local color printer, cut out, and folded into a tangible solid model. It should, perhaps, be mentioned that while still a relatively simple and early version, the Platonic Solids Applet nonetheless required upwards of 1000 lines of Java code to implement (largely due to the still embryonic state of Java environments and libraries).

The screen appearance of the Platonic Solids Applet is shown in [Fig. 1]. At upper left, a photograph of five solid models is shown; when the user selects one of these (via a mouse-click) the folding net for the chosen solid appears in the larger area toward the right of the screen. [Fig. 2] depicts the result of selecting the icosahedron model (composed of twenty equilateral triangles); here the folding net for the icosahedron is displayed. This net may then be decorated by a variety of means supplied by the paint tools region at bottom left. In [Fig. 2], the user has employed these tools to add a circle, rectangle, line, and "scribble" decoration to the net; she has also filled several of the triangles in the net. The paint tools support these sorts of decorations in the standard manner: for instance, to create a circle, the user chooses a color (from the pre-supplied set in the paint tools box), and then chooses the "circle" radio box. She proceeds to press the mouse button down at the point where the desired circle should be centered, and holds the mouse button down, dragging the mouse cursor to the desired radius of the circle before releasing it. [Fig. 2] depicts a similar (and likewise standard) method for drawing a "scribble" in freehand fashion using the mouse.

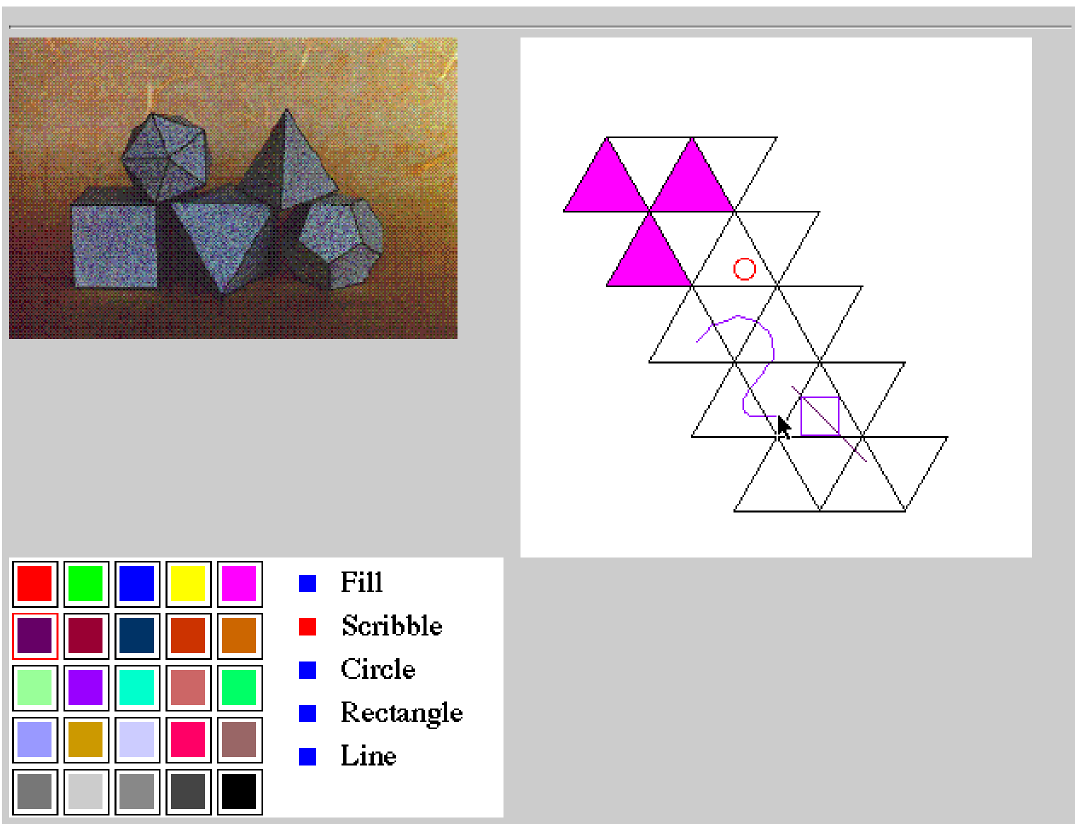

Figure 2: The process of decorating a net for the icosahedron (the shape at upper left in the photograph).

(Sun Microsystems, Inc., Mountain View, CA). The applet may be viewed by following a pointer from the URL:

http://www.cs.colorado.edu/~l3d/systems/hypergami/

Note that the character "l" in "l3d" is a small "L", not a numeral "1".

In its implementation, the Platonic Solids Applet represents an initial step in combining our existing HyperGami system with Web-accessible tools and activities. While the user of the applet may, for instance, decorate folding nets, she cannot do so in nearly the range of methods available in HyperGami (which include patterns, textures, programmable gradients, and turtle graphics, among many others). Perhaps more importantly, the central activity in HyperGami is the design of new, never-before-seen custom polyhedra; this is achieved by applying a variety of "customization operations" to starting shapes. [Fig. 3] illustrates the idea: here, we have begun with a HyperGami icosahedron; we have "sliced off" the upper portion of that shape; stretched the remaining portion; and finally, added a "prism cap" at the top of the shape. The HyperGami system is then capable of unfolding this shape to yield the folding net depicted in [Fig. 3].

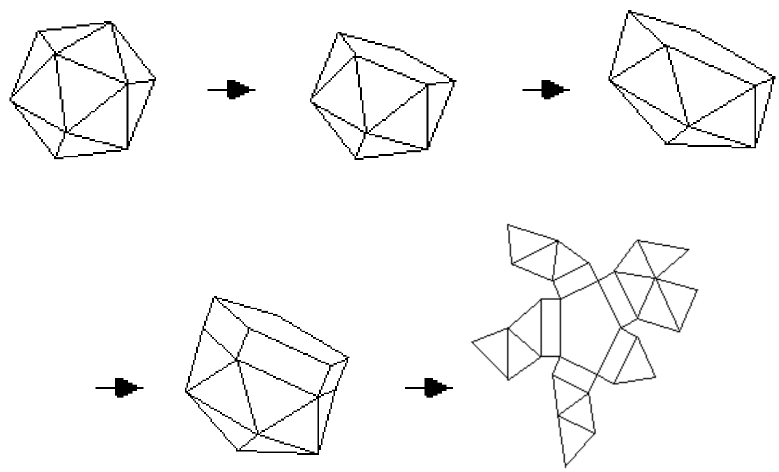

Figure 3: Designing a customized polyhedron in HyperGami. An icosahedron is sliced, stretched, and capped; the "unfolded" pattern is shown in the final stage.

The Platonic Solids Applet is, in its current stage, intended only for the decoration of existing HyperGami solids (our running version includes the five regular solids, but other photographs and solids would of course be feasible additions). The applet cannot be used, however, to design new solids and nets; for this, the full HyperGami system would still be needed.

III. An Interactive Children's Book Blending Mathematics and Art

The Platonic Solids Applet, besides making HyperGami polyhedra available over the Web, is also part of a broader and more ambitious project in mathematics education—one including both traditional and distance learning media. We have recently completed a set of polyhedral constructions for a mathematical children's book entitled "AlphaBetaHedra"—an alphabet book of paper sculpture. In this book, each letter of the alphabet is represented by a photograph of a paper sculpture based on classical polyhedra. Two examples are shown in [Fig. 4]: the letter "F" (for "finger puppethedra") and the letter "G" (for "greenhousehedron"). Elements of these sculptures include the dodecahedron (the head of the pirate finger puppet), the cuboctahedron (on which the body of the soldier finger puppet is based), and the small stellated dodecahedron (the "flower" shapes in the greenhouse).

Our goal in developing "AlphaBetaHedra" is to combine the book with activities (or perhaps partial constructions) that are available over the Web. Readers of the book might be supplied with folding nets for some of the constructions in the book; other constructions could be made available through means such as those suggested by the Platonic Solids Applet. In this fashion, the Web would not be used as a primary means of presenting educational material, but rather as a means of enriching the potential of traditional media. It should also be mentioned that "AlphaBetaHedra" is only the first of what we hope will be a series of books designed in the same spirit—i.e., books that refrain from "preaching" mathematics and instead integrate the subject into a more natural and uncontrived framework in children's literature. We are currently at work on a book that moves beyond "AlphaBetaHedra" to include a narrative, fantasy-like story line.

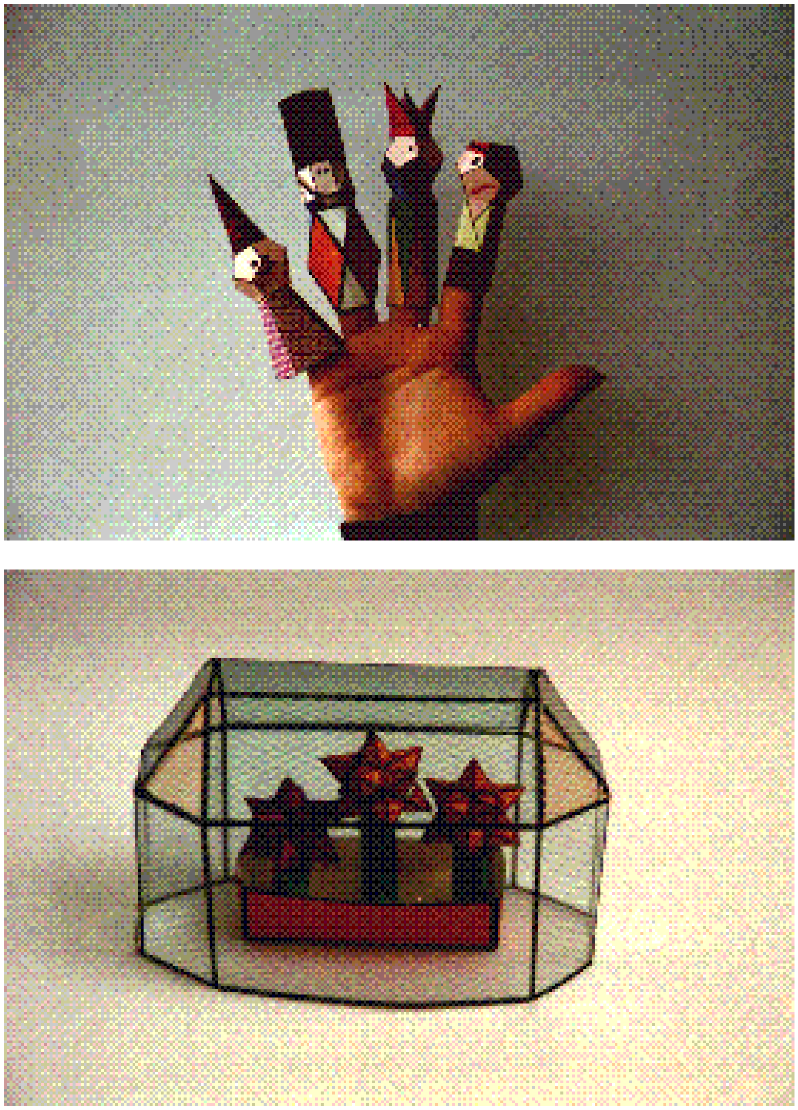

Figure 4: "F for finger puppethedra" and "G for greenhousehedron" from *AlphaBetaHedra.*

IV. Further Directions in Using the Web to Support Computational Crafts

There are certain obvious advantages to using the World Wide Web to support tools like the Platonic Solids Applet—and, more generally, to support the integration of computational media and handicrafts. Extended communities of students (and professional craftspeople) may share insights, experience, and advice; even more interesting, they may share specifications for constructions in various stages of completion. We can envision, for instance, the creation of HyperGami paper sculpture exhibits—real-world exhibits, existing in actual studios—that may be visited both in "real life", and over the Web, and that may be extended by their visitors. (People might, for example, send in folding nets for new constructions which could then be printed out and constructed by member of the exhibit staff "on-site.") In this fashion, a physical space of crafted objects may be enjoyed, studied, and contributed to by a widespread group of enthusiasts.

Despite these optimistic scenarios, however, we feel it important to note that there is an inevitable—perhaps productive—tension between the "virtual" aesthetic of the World Wide Web and the homey, earthbound pleasures of working by hand, with traditional materials. Our own feeling is that systems such as HyperGami and its eventual Web-based cousins—indeed, technological systems generally—should be judged according to how well they enrich the totality of lived experience, both physical and virtual. As Allucquere Rosanne Stone writes, "[I]t is important to remember that virtual community originates in, and must return to, the physical.... Even in the age of the technosocial subject, life is lived through bodies." [Stone 1991] For our part, in a world increasingly defined by the apparent freedom of the disembodied community, we sense a certain longing for the restraints embodied by the behavior of paper, wood, clay, glass, metal, and wax. We hope that innovations such as the World Wide Web may eventually help to intensify the human relationship with materials, and thus to soothe the tensions that they have played such a large part in creating.

Acknowledgments

We are indebted to the ideas and encouragement of Hal Abelson, Michael Mills, and Jim Spohrer, among many others. Thanks to Gerhard Fischer and the members of the Center for Lifelong Learning and Design at the University of Colorado for providing an intellectual home for our efforts. This work has been supported in part by the National Science Foundation and the Advanced Research Projects Agency under Cooperative Agreement CDA-9408607, and by NSF grant REC-961396. The first author is supported by a fellowship from the National Physical Science Consortium; the second author by a Young Investigator award IRI-9258684. Finally, we would like to thank Apple Computer, Inc. for donating the machines with which our research was conducted.

References

[Benedikt 1991] Benedikt, Michael (1991). Introduction to M. Benedikt, ed. *Cyberspace: First Steps*. MIT Press, Cambrdige, MA, pp. 1-25.

[Eisenberg & Nishioka 1997] Eisenberg, Michael and Nishioka, Ann (1997). Creating Polyhedral Models by Computer. To appear in the *Journal of Computers in Mathematics and Science Teaching*.

[Mühlhausen 1993] Mühlhausen, E. (1993). "Riemann Surface—Crocheted in Four Colors." *Mathematical Intelligencer*, 15:3, pp. 49-53.

[Negroponte 1995] Negroponte, Nicholas (1995). *Being Digital*. Vintage Books, New York.

[Pedersen 1988] Pedersen, J. (1988). Why study polyhedra? In M. Senechal and G. Fleck (Eds.), S*haping Space: A Polyhedral Approach*, pp. 133-147. Boston: Birkhäuser.

[Stone 1991] Stone, Allucquere Rosanne (1991). Will the Real Body Please Stand Up? Boundary Stories about Virtual Cultures. In M. Benedikt, ed. *Cyberspace: First Steps*. MIT Press, Cambridge, MA, pp. 81-118.

[Turkle 1995] Turkle, Sherry (1995). *Life on the Screen*. Simon & Schuster, New York.