

Abstract

In a creative final project, multivariable calculus students will create an art sculpture and have the opportunity to have their "sculpture" project printed on a 3D printer.

Course enhancement

The multivariable calculus projects in Math21a are traditionally creative. Figure 1 shows two examples from the past. Our Math21a course is a standard multivariable course which extends single variable calculus to higher dimensions. It not only provides vocabulary and background for understanding fundamental processes and phenomena in economics, life sciences, finance or chemistry but also builds tools for describing geometrical objects like curves, surfaces, and solids. This helps to form intuition which is needed in other fields like computer vision or data visualization or medical sciences. In 21a, students are also exposed to a powerful computer algebra system which allows exploration of space without any programming experience. It helps to sharpen visualization skills. An important part of multivariable calculus has always been link to artistic components like architecture or music. These connections have been lived traditionally in our courses for decades.

This summer, I will use a 3D printing printing component the first time in the summer school. I will not have the budget to print all of the student creations but print the best ones. In the summer course of 2012, the project already will be "**build an art sculpture**". I will just select a winner and print that one. In the fall project, students will be asked to build a sculpture for display, either inspired by previous art or a new creation by the student. With a grant, we would be able to print them. In this project, **art and mathematics will meet and come to live** with the exciting **emerging technology of 3D printing**.

Budget

Printing a single object costs about 25 dollars in Shapeways which produces high quality 3D printouts. This is easier and much better than any consumer 3D printer can do. Objects can be submitted electronically and will be sent back by mail. With an estimated 200 student enrollment, we can build 200 creative objects, mathematical sculptures and make an exhibit. The following line item details are chosen to match the 5000 dollar grant. Depending on material this can be adapted:

Prize for one Printout	25 Dollars estimate (http://www.shapeways.com/materials)
Number of Students	200 Students estimate
Total	5000 US Dollars

Class exhibit examples

Student gallery exhibits have tradition in math21a, math21b. Examples:

<http://www.math.harvard.edu/~knill/galleries>

<http://www.courses.fas.harvard.edu/~math21a/exhibits/garden>

http://www.math.harvard.edu/archive/21a_fall_06/marblebook

http://www.math.harvard.edu/archive/21b_spring_08/exhibits/songs

Previous grants

Here are previous projects crossing disciplines. Examples:

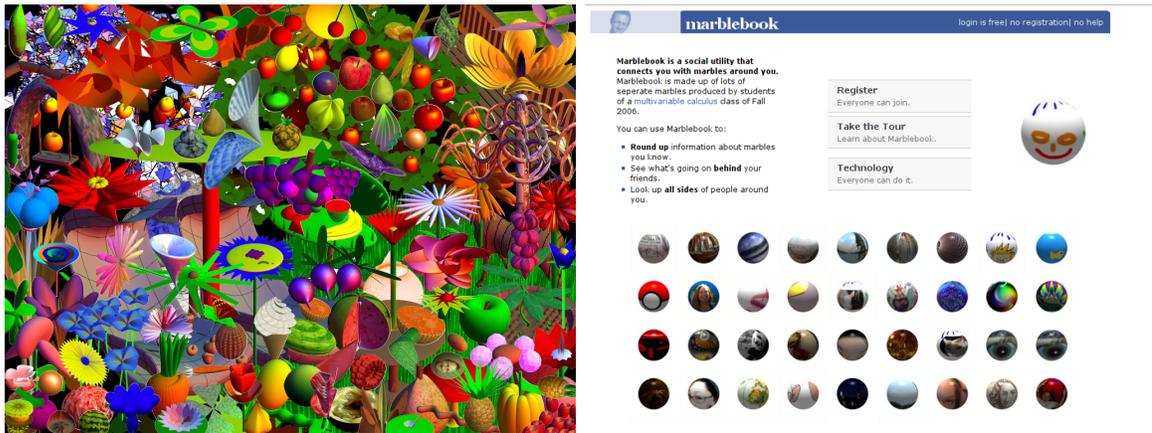


FIGURE 1. A garden project with more than 200 objects built by our Harvard Math21a class in Fall 2011. The task had been to build a fruit, plant or garden object. The right figure illustrates "marblebook" a spoof on Facebook. This project was built by the Harvard Math21a class in Fall 2006. More than 300 marbles were rendered from pictures submitted by the class. It illustrates the parametrization of surfaces.



FIGURE 2. The sculpture "anachron" by Artist **Bathsheba Grossman**, rendered in the computer algebra system Mathematica, realized in bronze by the artist and printed by a 3D printer in shapeways.

- One is a PITF project on exploring vector fields
<http://www.math.harvard.edu/~knill/pitf>
 from summer 2004 with the Harvard presidential fellow **David Mahfouda** who concentrated in the department of visual and environmental studies.
- A visually centered project was a year long HCRP project of 2009 with **Michael Teodorescu**
<http://www.math.harvard.edu/~knill/caustic/exhibits>
<http://www.math.harvard.edu/~knill/conchoid/exhibits>
- The extension school thesis project of **Jose Ramirez** was artistic in some way because the developed software allows image analysis and redrawing. The exhibit page is here:
<http://www.math.harvard.edu/~knill/3dscan2/exhibits>
- Finally, I direct an extension school thesis project of **Elizabeth Slavkovsky** which deals with 3D printing in education. I have learned a lot during this project about the technology of 3D printing. Liz also has her own printer and we have used the technology to demonstrate volume computation by slicing. Here is the exhibit which is built up:
<http://www.math.harvard.edu/~knill/3dprinter/exhibit.html>