Art to Engineering: Pervasive RP activities at Arizona State University

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Abstract

We present a sampling of widely diverse Rapid Prototyping activities at ASU. Through the interdisciplinary PRISM project, RP is firmly involved in three areas: education, research and outreach. Two courses have been developed, one teaches RP over the web and the other Visualization and RP as applied technologies aimed at interdisciplinary graduates and seniors. Researchers and students from Engineering, Architecture and Industrial Design, Fine Arts and Liberal Arts and Sciences and Business actively use RP. A recent formation of the PARfC (PRISM Advanced Rapid-fabrication Consortium) Consortium with local industry will create a local and formal center for research, education, service and training in Rapid Fabrication.

Introduction

Description of PRISM

PRISM stands for Partnership for Research In Stereo Modeling. PRISM was established over two years ago at ASU to promote interdisciplinary research in the areas of 3D Data acquisition, Visualization and Modeling, and Form realization. PRISM researchers come from diverse backgrounds such as Biology, Fine Arts, Archaeology, Anthropology, Computer Science, Mechanical and Industrial Engineering to name a few. The common interest among various disciplines in 3D and higher dimensional data sets is the key motivation for PRISM.

Description of PAR_fC

Many rounds of discussions and need for a joint Rapid Prototyping and Fabrication research between local companies such as Motorola, Allied Signal, Boeing, PADT, Raytheon and Toy Time Inc., led to the formation of the PRISM Advanced Rapid-fabrication Consortium. The goals of the PAR_fC consortium are three fold, i.e. Education, Research and Outreach.

Equipment and Lab setup

PRISM currently operates one lab in the Goldwater Center and is in the process of establishing two mores labs including the Rapid Fabrication Consortium facility. The lab is equipped with high end SGI and NT workstations, Virtual Reality setup, 2 Cyberware laser digitizers and three rapid prototyping machines including the Genisys (plastic), FDM1650 (ABS and wax) and a JP5 (manual feed paper). The lab is equipped with commercial software such as I-DEAS, PRO-E, Maya (Alias) etc. and also in house software. With the formation of the consortium, we are looking to add a DTM machine to our lab.

We describe in this paper various interdisciplinary activities at PRISM and Arizona State University concerning RP. These are categorized below under Education, Research and Outreach.

Education

The education component includes providing opportunities for all students from college freshmen through life-long learners. It means learning both on and off campus, with university and industrial teaching and mentoring. For education in Rapid Fabrication (RF) to be effective it needs both theory and practice. The capabilities must be cutting edge in pedagogy and technology. The result will be graduates and practitioners who can bring the most recent ideas and techniques to industry and continue to push the RF envelope. We have several RF education programs already in place. They are as follows:

Courses

Three courses were offered specifically in rapid prototyping during the 1997-98 academic year.

- IEE591C - Industrial engineering course combining one-third RP and two-thirds mechatronics. A full version of the Rapid Prototyping course will be offered on campus in the fall 1998 as IEE591A.

- IEE591 - Web based version of the RP course offered to students on the web at Oklahoma State University, Allied-Signal and Boeing Helicopter.

- ART591 – VIZProto, Interdisciplinary 3D visualization and rapid prototyping course offered to students across disciplines. Students applied the technology in 3D scanning, modeling and rapid prototyping. Student projects are available at http://surdas.eas.asu.edu/~razdan/Class/3dvizrp.

We give three examples from the student projects. The first project was to design and make a functional prototype for a tape measure. The model was designed on Form-Z CAD package and various design parameters were noted. These were compared against the dimensions measured from the rapid prototyped model (see Table 1). The model was built on a Genisys. The differences were attributed to resolution limitation of the RP machine. After only minor finishing the tape measure was functional. Figure 1 is the concept design and Figure 2 is a picture of the actual model. The comparison resulted in characterization of the Genisys machine.

	Part	Form-Z Model	Stratasys Model
A	Total width	3.3350	3.3700
B	Total height	2.7100	2.7050
C	Shell thickness	0.1000	0.1170
D	Shell at thinnest	0.0450	0.0680
E	Rail's diameter	1.5000	1.5120
F	Rail's thickness	0.0625	0.0705
G	Tape mount	0.3200	0.3350
H	Post height	0.9800	0.9755
I	Post diameter	0.1600	0.1630
J	Pin diameter	0.1800	0.1970
K	Pin base diameter	0.3000	0.3200
L	Shell height	0.6250	0.6320
M	Pin height	0.8250	0.8335

N	Mini-Pin diameter	0.0900	0.1000
O	Mini-Pin hole	0.0900	0.0800
P	Screw hole	0.0800	0.0800
Q	Pin hole	0.1800	0.1690

Table 1: Part design parameters and as measured from the prototyped model

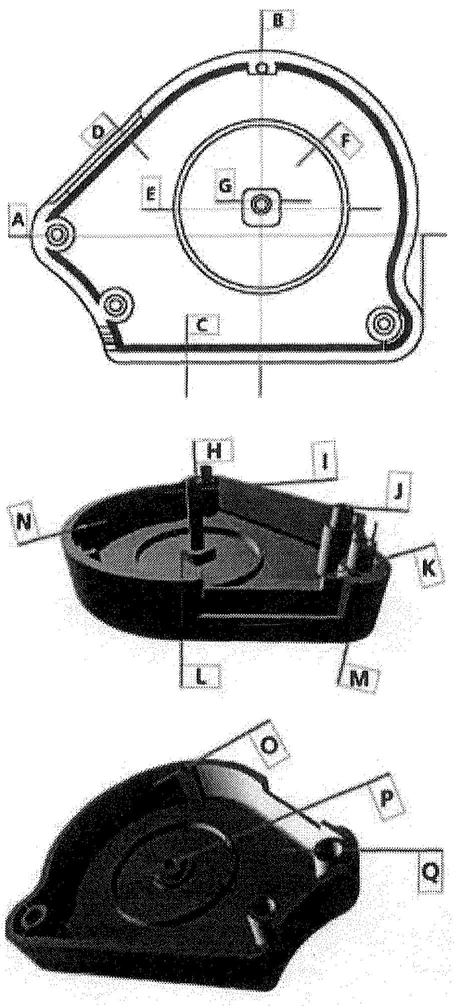

Figure 1: Concept Design for the tape measure

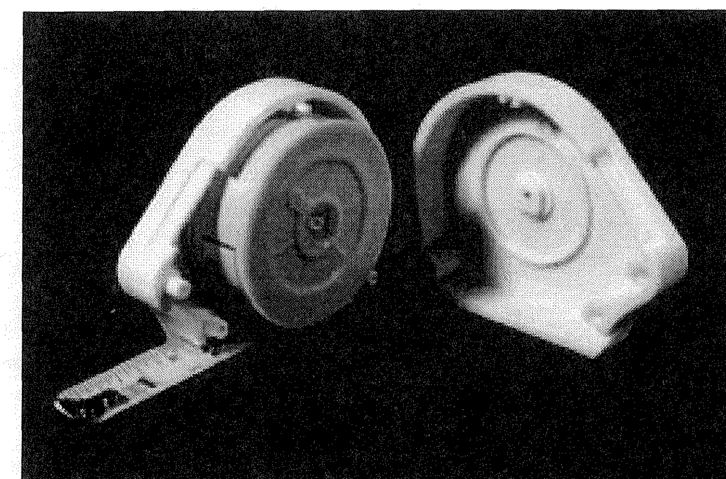

Figure 2: Picture of the tape measure model

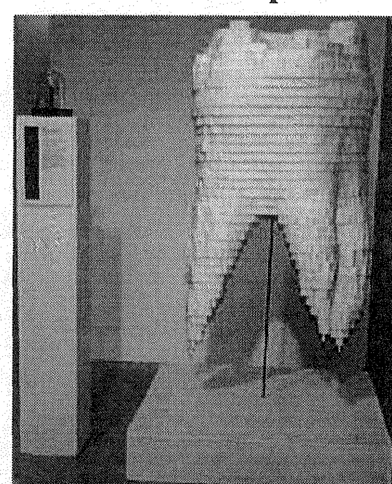

Figure 3: Scaled prototype of the tooth

The second project involved making a scaled prototype. This project combined the high technology of 3D scanning with a more low-tech approach to sculptural prototyping. Initially, an extracted wisdom tooth was scanned using a Cyberware 3D Laser Digitizer. Although much of the tooth scanned with surprising clarity of detail for an object so small, certain problem areas lacked accurate data. The most notable of these areas was where 2 of the roots were quite close together, creating a visual overlap from the digitizer. Using QuickSlice, the proprietary software from Stratasys, the three-dimensional computer model was first repaired, and then *sliced* at even intervals. Each of these 40 layers was projected onto styrofoam and the outlines were traced by hand. The layers were hand-cut with a hot wire and assembled to form an enlarged replica of the original object. See Figure 3. Not clearly visible, but the original tooth is in the glass case on the top left of the image.

Design Projects

The lab was used by students in both the courses listed above and other course projects offered throughout the year. A large number of student design projects were built in the RP lab during the spring 1998 Semester. The table below shows the number of parts and amount of material used. It should be kept in mind that even though the activity is fairly high, this year was the first to have these two machines and their availability was not generally publicized. One notable senior design project was the assembly of the 48 piece articulated landing gear (See Figure 4). Table 2 notes the RP activity during the spring 1998 semester.

RP Machine	Capabilities	No. of Parts	Material Used
Stratasys Genisys	Lower resolution, faster, polyethylene parts	70-80	25(*$100) cartridges
Stratasys FDM1650	Higher resolution, slower build, ABS, wax and support structure materials	88	2 spools each of modeling ($153/spool) & support material ($75/spool)

Table 2: **RP Production at ASU, Spring 98**

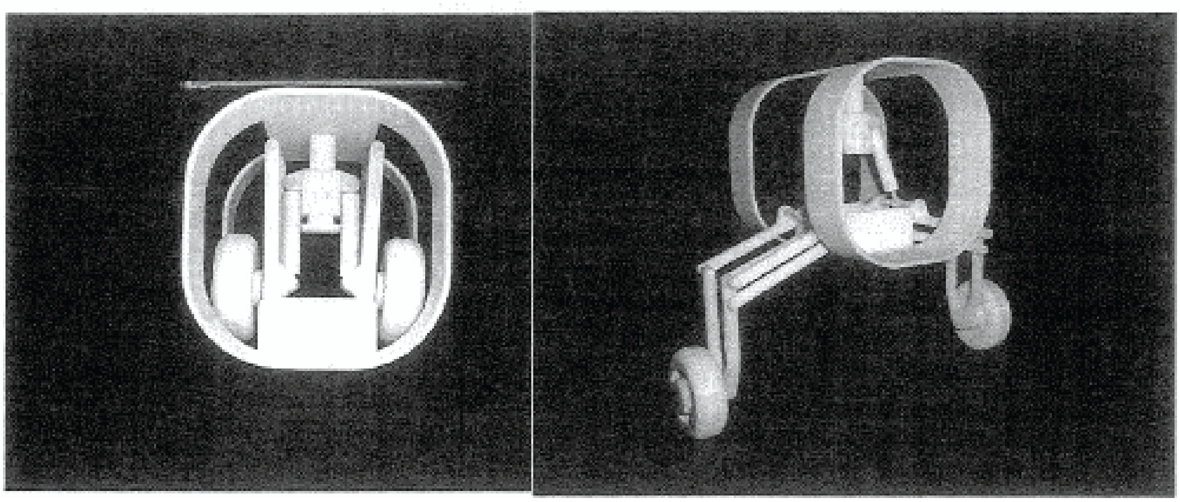

Figure 4: Two views of the 48-Piece Articulated landing gear

Programs Under Development

We are proposing to develop the following programs as part of the educational offerings. These include Industry Internships, ASU Internships and Seminars/Conferences. These would facilitate exchange of ideas and rich experience for the students and industry alike.

Research

Current Projects

The following paragraphs describe ongoing and completed research projects both within and outside of PRISM in the area of Rapid Fabrication. These activities form the basis for research in PAR_fC.

1) Optimizing Part Orientation for Surface Finish, Gautham Kattethota and Mark Henderson.

   We are developing a software tool to calculate the expected surface finish quality of all surfaces on a RP model during the build process. Sample RP parts were fabricated with a variety of surface orientations. The surface finishes were characterized using a Sheffield Surface Scanner at Allied Signal (Tempe). Data have shown an unexpected, yet predictable surface finish based on several build factors. The software tool will allow the user, through the use of color codes, to compare desired and possible surface finish specifications during interactive part orientation and to select the optimal build orientation. A paper on this is presented at the SFF 98 conference.

2) Reverse Engineering From Scanned Data, Ben Steinberg, Anshuman Razdan, Gerald Farin, NSF

   The goal is to reduce and convert the data from a digital laser scan into a NURBS surface for reverse engineering and to create a parametric solid model. A paper on this is being presented at the SFF 98 conference.

3) Scientific Visualization Using Tactile Feedback, Anshuman Razdan, NSF.

   This is the second year of the two-year NSF funded project to make RP models of microscopic and mathematical images to help visually impaired visualize scientific data. Work continues on transforming various 3D data to RP and incorporating surface texture.

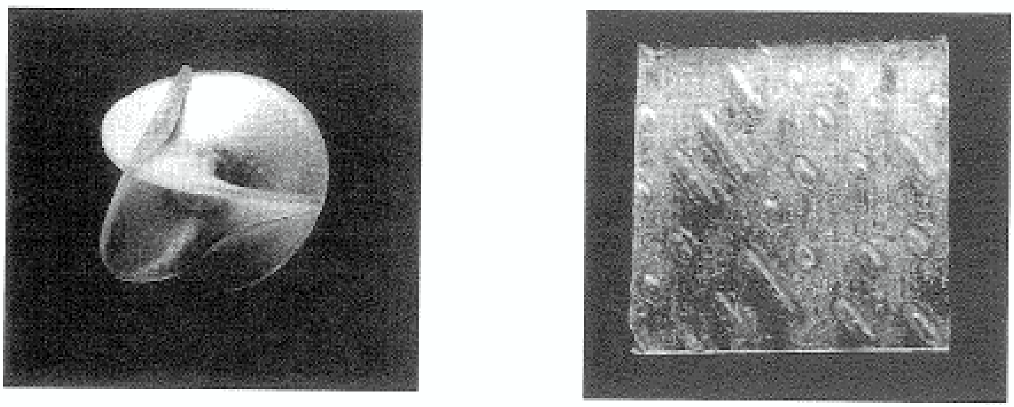

Figure 5: An enneper surface and CDROM microscope sample

Figure 5 shows two samples from the project (http://surdas.eas.asu.edu/~tactile).

4) Virtual Sculpting (HERA Project), Carl Dahl, Alyn Rockwood, Geoff Duke, Jeff Dorman, Mark Henderson.

   Interactive shape modification through 3D input to a virtual lump of modeling material creates geometric solids, which can be viewed and prototyped. The user can morph the shape through hand gestures and produce a plastic prototype or solid model as output. This project is aimed at conceptual design (Figure 6).

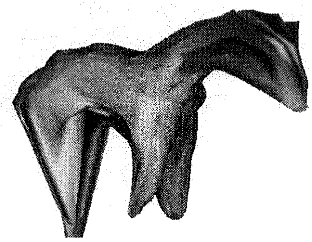

Figure 6: A shape of a horse using Virtual Sculpting

5) STL File Repair, Surya Suluh, Mark Henderson and Anshuman Razdan.

   Using algorithms for redundant vertices, missing and overlapping facets, flipped surface normals and unmatched facet edges, a program was developed to repair damaged or problematic STL files automatically and to review both the errors and results graphically. This was a M.S.E. project (finished May 1998).

6) Process Planning For Rapid Machining, Norma Hubele, Chell Roberts, Mark Henderson, NSF

   The second 3-year phase of this NSF funded research will develop a tool to provide manufacturing advice to a designer in order to achieve minimum NC machining time, minimum cost or maximum part quality. NC machining is another way to do rapid fabrication.

7) Metal Spray Deposition for Rapid Fabrication, Ampere Tseng, Various agencies

   A new, patentable process is being developed to create quick metallic prototypes using metal spray.

8) Preserving the past in 3D

   A recent collaboration has brought the Archaeological Research Institute (ARI) at ASU in partnership with PRISM to create three-dimensional database of archeological artifacts. The ARI at ASU has been the keeper of Native American artifacts that were excavated during the Central Arizona Project. Recently, Congress passed the Repatriation Act, which entitles the Native American tribes to gain possession of these artifacts and rebury them. This will result in the permanent loss of a great amount of scientific data whose only record would be through photographs and subjective description. However, with the joint effort all the artifacts will be digitally scanned before returning to tribes thus preserving true 3D data set. We have successfully reproduced scaled model replicas using the RP equipment at PRISM (see Figure 7).

9) The Capitol Project.

The original idea to create a model of the State Capitol Building came out of recent

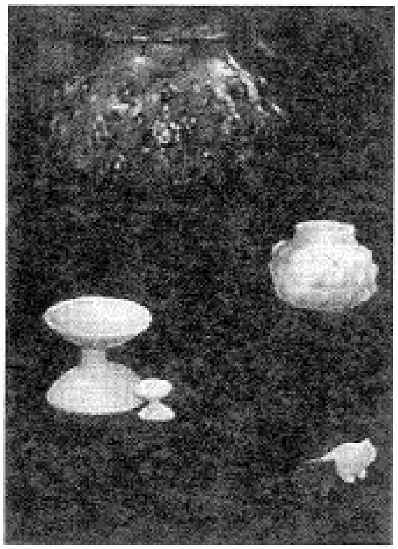

Figure 7: Archaeological artifacts reproduced

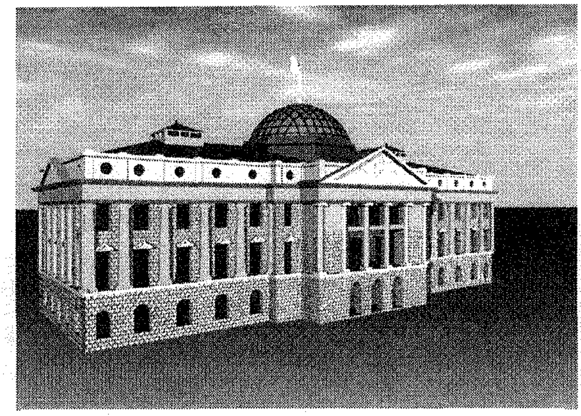

Figure 8: The Capitol Project

investigations into the Capitol Mall district and possible urban renewal projects. The Capitol Building model was built to symbolize a renewed commitment and to celebrate its 100 year anniversary. Architectural plans from 1898 were loaned by the Arizona Department of Administration. Details that could not be translated from the plans were digitally photographed or measured directly off the building. The computer model was created using FormZ solid modeling software. Several iterations of the model were produced on the two rapid prototyping machines. A scale model of the original Winged Victory figure that adorns the top of the Capitol was made available by the Arizona State Archives and was scanned in and prototyped. The two models were then translated into bronze casting via silica shell casting at the ASU Art foundry.

The Research Roadmap

The following high impact areas have been recognized for emphasis on RF research: Metal fabrication, Non-metal Fabrication, Hybrid Materials, Geometry issues and Prototype Size/Scale. The following table (Table 4) includes an attempt to categorize the ongoing projects enumerated in section Current Projects.

Rank	Research Topic (Top 5)	Specific Issues for Each Topic	Ongoing Projects
1	Metal Fabrication and Rapid Tooling	Precision tooling; direct injection molding tools; dimensional stability and accuracy, material uniformity and properties	7,8
2	Issues of Scale	Ability to produce nano- through mega-size parts; minimum feature	1,3,4

		sizes; part joining; removing need for segmentation	
3	Non-metal part materials including ceramics	Predictable and tunable material properties; Increased range of materials; Dimensional stability and accuracy	3,4,6,7,8
4	Hybrid and composite materials	Fabricating non-homogenous materials; intentional inclusion of varied material features; combining fabrication and assembly	
5	Geometry/CAD and file format issues	Self-repairing STL files; Pursuit of STL alternative format; Optimal discretization; Software for optimal fabrication parameters including orientation	1,2,4,5

Table 1: The High Priority Research Issues

Outreach

Outreach is the process in which ASU shares knowledge and technology transfer with the consortium members and other partners. We envision the consortium to have an effective outreach program with the complete supply chain including Large Corporations, Small and Medium Sized Companies, Company Vendors, Rapid Fabrication Equipment Manufacturers and the university. The service is centered around both Large Corporate Members (LCM) who have already invested and adopted RP and Small and Medium size Enterprises (SME) who want to become involved. Service Bureaus are also important in PAR$_f$C. Many SMEs are interested in the technology but are turned off by the investment, both financial and staff costs.

Many industries in the region are involved in manufacturing and other activities that could benefit from incorporating RF. Some are not yet aware of the capabilities or the basics of the technology. For example, Toy Time Toys, Inc., a small entertainment concept design company recently interacted with PAR$_f$C to create the next generation of a sporting item to be unveiled during SuperBowl 1999. The design and prototype were taken on as a student project. This was the company's first experience with 3D CAD design and RP. The company is convinced of the advantages the technology provides.

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