

## **AC 2007-359: REMOTELY ACCESSIBLE LABORATORY FOR RAPID PROTOTYPING**

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Dr. Nasir Ghani is an Associate Professor of Electrical and Computer Engineering at TTU. Prior to joining TTU, Dr. Ghani has accumulated over 8 years of software and telecom industry experience and has held senior positions at Nokia, IBM, Motorola, and several start-ups. At TTU he has quickly built up a strong externally-funded research program and has established a state-of-the-art networking lab. Most recently, he received the NSF CAREER Award (2005) to conduct advanced research in multi-domain/multi-layer high-speed networks. He received his PhD degree in electrical and computer engineering from the University of Waterloo, Canada.

# Remotely Accessible Laboratory for Rapid Prototyping

## Abstract

The Rapid Prototyping (RP) Laboratory<sup>1</sup> was established in Fall 2003 and funded by the National Science Foundation DUE 0311586 grant and Tennessee Tech University (TTU) matching support. Since this time, almost 500 high school students and student(s) studying computer aided design/computer numerical control have practiced with RP technology. In order to further extend a remote access capability to this current laboratory and let more engineering and technology students learn this technology via online materials, a new NSF grant was awarded in Summer 2006<sup>2</sup>. Since this time, the remote RP laboratory development has been in progress. Workshops for Pre-K16 (P16) teachers have been organized for the dissemination of RP and this project. A project website<sup>3</sup> has also been developed and feedback collected via an online poll. The scope and current development of the project will be reported in this paper.

## Introduction

RP is expressed as a group of techniques used to quickly produce a scale model of a part using 3D computer aided design (CAD) data. The methodology behind the RP process is an additive technology which builds the parts layer by layer. RP was first developed in the late 1980's. Since then various RP techniques have become available in the market.

There are various motivations in implementing RP technology. Foremost, this technology decreases product development times while dramatically lowering costly expenses. Namely, detailed RP models can be used for testing, modeling, visualization, patterning, and analysis.

The basic steps for all RP techniques can be generalized as follows<sup>4</sup>:

- A CAD model of the target part is constructed, and then converted to an STL file format.
- The RP machine processes the STL file by creating sliced layers of the model.
- The first layer of the part model is created at the machines. The model is then lowered by the thickness of the next layer and the process is repeated until the completion of the model.
- The final RP produced part and its support structures are removed. The surface of the part is then post processed and cleaned.

The extra steps integrated into the current TTU RP laboratory to make it remotely accessible are

- To develop an accessing interface to view the lab live.
- To set up webcams so that students feel like they work in a real RP lab environment.
- To establish some scheduling tools so that students can identify their part submission and delivery dates online.
- To form some kind of communication mechanisms to communicate to the lab staff.
- To deliver the RP produced part back to student on-time.

## **Background**

Distance Education is becoming an increasingly important means of delivery for many institutions of higher learning. Many universities (including TTU) offer a full range of on-line courses that make education accessible to those who do not fit the model of traditional full-time student and/or have budget limitations. Here advanced Web-based learning tools, e.g., such as WebCT and Blackboard, have played a critical role in simplifying the task of offering lectures over the Internet. However, while Web-based instruction works well for lecture courses, educational programs that rely heavily on a “hands-on” learning approach must develop novel and more meaningful laboratory-level processes that can be delivered over the Internet. Today, this is an active focus area for many universities and various distance learning/education setups are being evolved towards a “remote lab” model.

Currently, the field of distance rapid prototyping education has not received much attention in the academic arena. Perhaps the only initiative to date has been the experimental Tele-Manufacturing Facility, which was setup jointly by the University of California at San Diego (UCSD) and San Diego State University (SDSU)<sup>5</sup>. This project developed a novel Internet-based access capability for a RP machine, and focused on the key technical concerns (without implementing in any educational setting), e.g., control software, job processing/scheduling, STL file verification, etc. Nevertheless, this project was primarily a research-type effort and did not consider any further inter-campus sharing or distance education applications. However, the UCSD/SDSU project represents a solid “proof-of-concept” of a remotely accessible RP facility and provides a good reference for future related efforts.

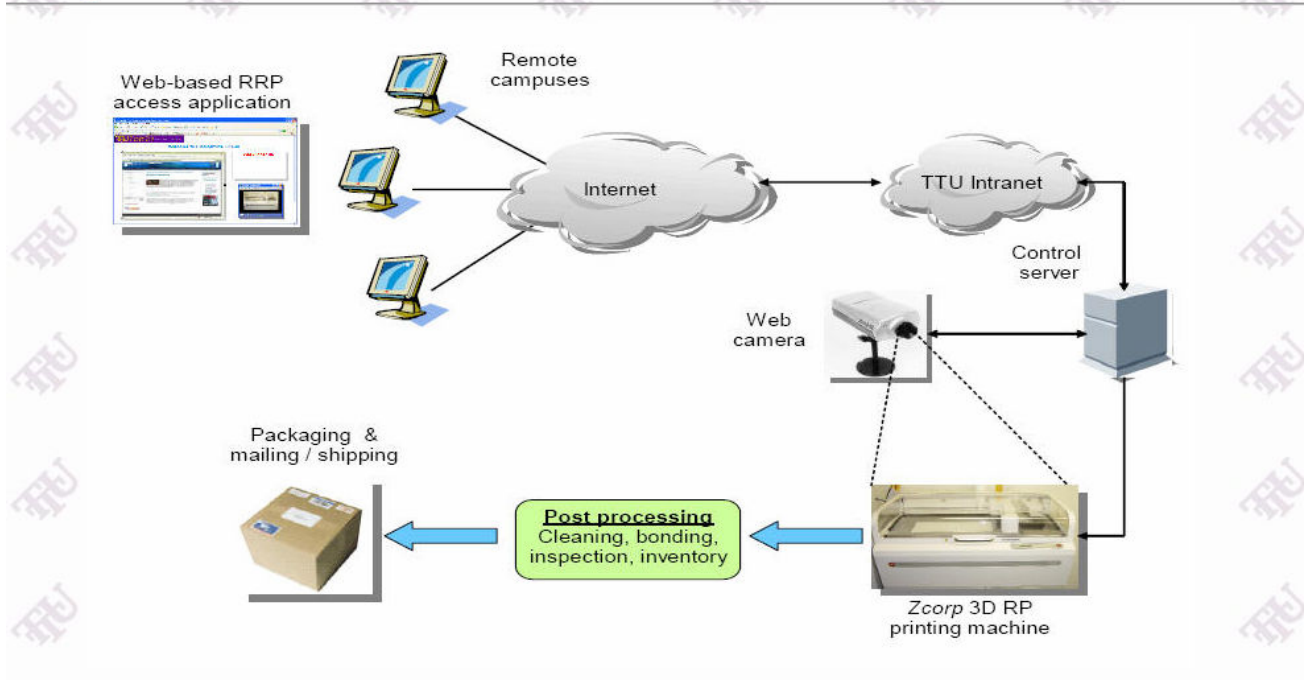
## **Current Development**

Currently TTU and its project partner, Saddleback College purchased servers, network cameras and various accessories to give a Web-based access to their RP facilities. Both sites are password protected and users can access these labs through their internet browsers. Any user can access the labs and virtually see the lab environment and current works going on in the labs as can be seen in Figure 1.



Figure 1: Rapid Prototyping Laboratory located at SC

Project Web site (see Figure 2) was also developed so that users can access the site and see the calendar of the events going on in the TTU and Saddleback College laboratories. The website also has various features related to project workshops, instructional RP materials, project team, project polls and other things.



TTU SITE  
close-view of RP process  
SADDLEBACK SITE  
TTU FACILITY  
SADDLEBACK FACILITY  
WORKSHOPS  
PROJECT TEAM  
INSTRUCTIONAL MATERIALS  
SCHEDULE  
PUBLICATIONS

Figure 2: Project website for remotely accessible Rapid Prototyping Laboratory

In addition, various P16 RP instructional materials have also been developed. These materials are basically PowerPoint files and basic concepts related to RP processes, RP trends, and the overall RP market. These materials were developed for the future distance delivery of a RP course planned to be offered through TTU.



### Project Evaluation

In order to receive solid feedback about the project's impact on student learning, a survey tool has been developed and circulated for the full board review of the Institutional Review Board (IRB) at TTU. TTU's IRB has approved the developed survey tool.

This survey has been used in a RP workshop held in summer 2006. Note that several P16 STEM instructors were invited for a day long RP workshop held in TTU in Spring 2006 and the same

survey form was used here. In addition, this survey was also used for principal investigator's MIT4450 RP course lectured in Spring 2006.

Table 1: IRB approved project evaluation instrument

	<b>Tennessee Tech University (TTU)</b> <small>Evaluation Form of the TTU Rapid Prototyping (RP) Project funded by NSF</small>			
Today's Date: _____	School/Company Name: _____			
Course/Workshop Name: _____	Job Title: _____ <small>(if applicable)</small>			
First Name: _____	Ethnicity: _____ <small>(check one)</small>	<input type="checkbox"/> Black or African American		
Last Name: _____		<input type="checkbox"/> White		
Gender <input type="checkbox"/> Male <input type="checkbox"/> Female		<input type="checkbox"/> Hispanic		
		<input type="checkbox"/> Asian or Pacific Islander		
		<input type="checkbox"/> American Indian or Alaskan Native		
		<input type="checkbox"/> Other (Please specify) _____		
Major: _____ <small>(if applicable)</small>	Age: _____			
Expected Graduation: _____ <small>(if applicable)</small>				
Have you ever practiced RP Technology before?				
Yes	No			
Have you ever seen or read anything on RP before?				
Yes	No			
What are the conventional manufacturing processes you practiced so far?				
_____				
What are the most important points in your RP practice/project? (1 less important, 2 moderate, 3 most important)				
___ Short production time of the part				
___ Seeing the physical model in a short period of time				
___ Integration of CAD and RP				
Where can you use RP in the future?				
_____				
Rate your satisfaction on your RP practice/project.				
Low	Moderate	Medium	High	Very High
Do you recommend having RP integrated projects in the other courses?				
Yes	No	No Opinion		
RP Practices increased my concentration/understanding in my field of study.				
Low	Moderate	Medium	High	Very High
RP is an excellent method to practice the Integrated Manufacturing (CAD/CAM/Casting/Plastics).				
Low	Moderate	Medium	High	Very High
RP helped me better understand my design practices/projects.				
Low	Moderate	Medium	High	Very High
Your Comments on RP Projects/Instructions:				
_____				

The survey results presented that conventional manufacturing processes are commonly used in students' daily life in education and industry. However attendees are targeting to use RP technology in various fields for their student projects, demos, and science fair mock-ups.

The results of the evaluations will be used to continually identify further areas for improvement and thereby increase the success rate of the remotely accessible RP laboratory and courses. Table 1 shows the developed survey tool.

## **Conclusion**

RP is an almost fifteen-year old additive production technology and not commonly practiced in many educational arenas. Due to the initial cost of the RP establishment, maintenance of the equipment and user training, most educational institutions are not able to have an in-house RP laboratory. The solution outlined in this project is a best practice replicable for many universities around the nation and an initial pioneering development for this advanced manufacturing technology. Initial developments and beta testing results are presented in this paper. Future developments and assessment studies of student learning with on-site versus online RP students will be presented in the upcoming ASEE or FIE publications.

## **Acknowledgements**

This project has been funded by NSF award number 0536509. Authors greatly appreciate the financial aids and technical support received from NSF, TTU's Center for Energy Systems Research, TTU's Research Office, and Saddleback College.

## **References**

- [1] [http://www.tntech.edu/mit/labs/rapid\\_proto.html](http://www.tntech.edu/mit/labs/rapid_proto.html)
- [2] <http://www.nsf.gov/awardsearch/showAward.do?AwardNumber=0536509>
- [3] <http://iweb.tntech.edu/rrpl>
- [4] [http://www.efunda.com/processes/rapid\\_prototyping/intro.cfm](http://www.efunda.com/processes/rapid_prototyping/intro.cfm)
- [5] M. J. Bailey, "Tele-Manufacturing: Rapid Prototyping on the Internet with Automatic Consistency-Checking," <http://vis.sdsc.edu/research/telemanufacturing.html>