

Rapid Prototyping-Distance Delivery Tools

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Abstract – Online courses and web-based laboratories are getting extremely popular in the 21st century. Institutional budget constraints and 24/7 accessibility features make the distance-based instructional deliveries very popular. This paper will report the remotely accessible rapid prototyping laboratory-and-online course practices at Tennessee Tech University. The development, implementation, assessment and dissemination efforts of these projects have been accomplished as part of National Science Foundation ATE and CCLI grants. The results of these current studies are presented with feedbacks received from the undergraduate level design and manufacturing students.

Keywords – Rapid Prototyping, Distance Learning, Online Courses, STEM, Remote Laboratory

I. INTRODUCTION

During the Fall 2007 semester, Tennessee Tech University's Rapid Prototyping course has been re-structured to offer a fully online laboratory component for students' practice. Students were able to prototype their parts through remotely accessible Rapid Prototyping Laboratory. Web-enhanced RP course students were also able to interact with students in Western Nevada College and prototype joint project parts with the campus-engineering students. TTU students and on-line WNC students have learned the cutting edge RP practices through TTU's Rapid Prototyping course.

In order to successfully accomplish the web-based hands-on laboratory practices and instructional deliveries, many distance course materials have been developed.

They are given as follows:

- 1) Remotely Accessible Rapid Prototyping Laboratory [1],
- 2) Web-based Instructional Delivery Support Center [2],
- 3) Desire2Learn Online Course Management Site [3],
- 4) WebCT Rapid Prototyping Instructional Delivery Site [4],
- 5) Moodle Open Source Course Management System Site [5], and

6) Rapid Prototyping P16 Information Center [6],

Most of the practices given above are also available through the National Science Digital Library [7]. NSDL is a free online library for education and research in science, technology, engineering, and mathematics--STEM. The NSDL Program was established by the National Science Foundation in 2000 as a free online library which directs users to exemplary resources for STEM education and research. NSDL provides an organized point of access to STEM content that is aggregated from a variety of other digital libraries, NSF-funded projects, publishers, and NSDL-reviewed web sites. NSDL also provides access to services and tools that enhance the use of this content in a variety of contexts. NSDL is designed primarily for K-16 educators, but anyone can access NSDL and search the library at no cost, although some content providers require a nominal fee or subscription to retrieve their specific resources.

Other than these six resources given above, the materials presented in the 2008 Rapid Prototyping Education Summit available at [8] are accessible via NSDL too. This current paper will only report the first three implementations highlighted before.

II. REMOTELY ACCESSIBLE LABORATORY

TTU and its project partner, Saddleback College purchased servers, network cameras and various accessories to give 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.

The basic steps for all RP techniques can be summarized as follows:

- 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 laboratories to make them remotely accessible are:

- To develop an accessing interface to view the lab live.
- To set up network cameras 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 interact with the lab staff. Adobe Acrobat Connect Pro tool has been used for such a task.
- To deliver the RP produced part back to student on-time.

Project Web site was developed so that users can access the website and see the calendar of the events going on in both 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.

The layout of the current lab is shown in Figure 1.

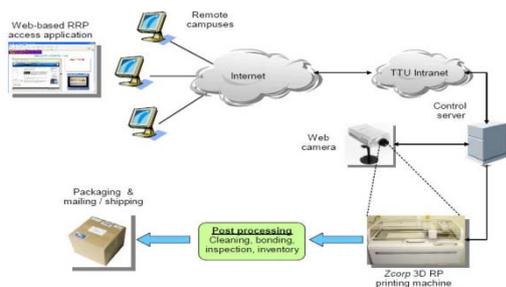


Fig.1. TTU's Remotely Accessible RP Laboratory

IV. RPIDS SITE

Several RP sites have been developed thus far. Most of them are available online and they are free for their users' industrial or educational needs.

Castle Island's information site contains various informational materials and links prepared in hypertext modes and it is commonly used for quick RP information needs [9]. The other information site is being developed by the

staff at the University of Utah [10]. This site is pretty similar to the one developed by Castle Island. The links draw broad attention from industrial and educational users. There are a number of similar sites to both developments [11].

Although there are many technological sites available in this emerging fabrication technology there is no existing knowledge base for use by educators, students and industry. Such a site should be a combination of educational panels, student information links and industrial knowledge sets. In order to address these needs, a modular site was developed by the researchers at Tennessee Tech University [2]. It is shown in Figure 2.

The base of the site is written in PHP. PHP is an acronym for "Hypertext Preprocessor". PHP is a scripting language that is the primary interface in MySQL website databases. It allows server-side interaction even for the novice programmer. It also maintains a high level of security and allows for scripts to be executed on the server rather than the end user's system. Although PHP can be used as end user scripts, all scripts on RPIDS run server side only.

For optimum compatibility, html wrappers are implemented for cross-platform reliability. The process of creating a site that is efficient and has a broad range of functionality is difficult. Most pages on the site implement a set of IFrames. IFrames, inline frames, allow multiple html pages to be shown in different frames on the same page.

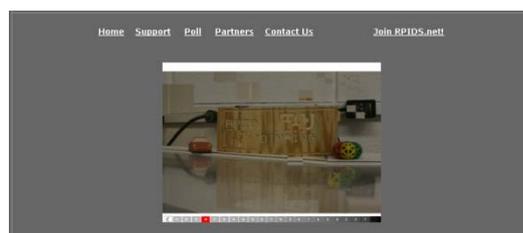
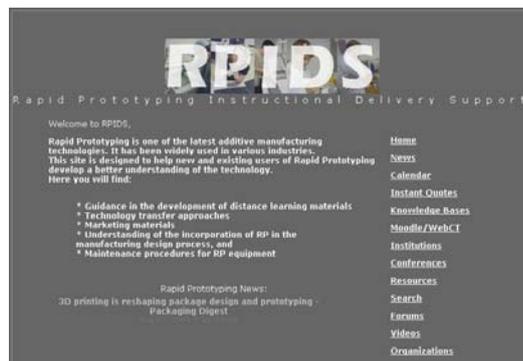


Fig. 2. Features of the RPIDS Site

A major source utilized by universities nationwide is the resources section of the RPIDS. There are many different file types that

are converted to universal standards. As compared to PDF's, the format by which most Microsoft Excel or Word documents are distributed, PowerPoints are a more complicated venture. PowerPoints are converted into Flash files. These load instantly on a high-speed connection, and can be viewed with free software. The end user can use any standard platform that has a version of Flash Player installed.

The image shown in Figure 3 represents a Flash Player utilized to view a PowerPoint file, a functionality that helps achieve the goal of accessing the files instantly at any location. There is a script that opens PowerPoints, now Flash files, full page in its own window. It uses JavaScript because the functionality cannot be accomplished within basic PHP scripting. It gives the files the look and feel of having them already loaded onto the user's system, enabling an instructor to walk into a classroom, pull up a PowerPoint file, and have an entire classroom of students display the presentation on their computers, without downloading or e-mailing a single file. All functions of the original PowerPoint, including notes and links, are still fully functional. This is very different from most online PowerPoint distribution systems. No complicated addresses or long list of instructions are required for the students to access the information.



Fig. 3. Instructional Resources in RPIDS

RPIDS site also incorporates an open area of extra resources to add to the functionality and interaction of the website. The contact mediums listed on the site allows a broader knowledge base for viewers looking for more information. This networking with other contacts, namely universities, helps promote an inter-institution community with others that are involved in the RP technologies.

These links are easily accessible from the home page and includes over 25 different institutions and laboratories for all users to access. RPIDS site maps is presented in Figure 4.

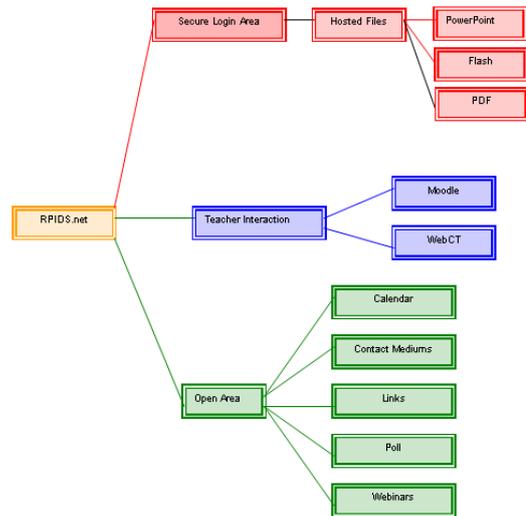


Fig. 4. RPIDS Site Map

Along with the Institutional contacts, a real time news ticker is located on the home page of the website. This ticker gives up-to-date information about RP and related topics. This function gives users a real world aspect of how RP is weaving its way through our everyday world outside of the collegiate and research atmosphere. Another tool that accomplishes the same thing is the instant quotes link which is located on the home page of RPIDS. This link offers a variety of companies that are solely involved in bringing your design into reality by RP in various different mediums. This allows user to understand and compare the different processes, associated costs, and delivery times.

A recently added poll allows users to input their views on the future development of the website. The end users are the most important people and giving them the tools and resources they need to learn is the main priority of RPIDS.

In order to record and tabulate the site access statistics, an account with ritecounter.com has been created. More than 1000 hosts and 3000 hits have been recorded up to August 1, 2009. The majority of the host and hit statistics have come from the educational institutions. The RPIDS site use was very high during the Fall and Spring semesters, but it was pretty low in Summer and Holiday Breaks.

V. D2L COURSE

TTU has been offering Rapid Prototyping courses since early 2004. This course is offered for the senior level college of engineering

students; but is also available to various art and science students. With the availability of a remotely accessible RP laboratory, course students were able to access the laboratory remotely and perform various team projects for their in-class assignments.

Since the course has been offered via D2L online course system, it was a hybrid course with its face-to-face instructional components. Laboratory practices have been accomplished with the help of a student assistant, who processed the parts and submitted them directly to student teams. In order to generate the 3D models, Pro/Engineer Wildfire software has been used and RP course students have learned how to use the software to generate their models in .stl part file format.

Instructional delivery and assessment have been accomplished via D2L system. D2L is a developer of online course management system for schools, higher education, associations, government and private industry. Headquartered in Kitchener, Ontario, Canada, President and CEO John Baker founded the company in 1999.

Today the company supports over 4 million students worldwide. Over 400 institutions are currently using D2L. Figure 5 presents the view of MIT4450 course D2L site.

Interesting features of D2L include

- Ability to create infinite number of roles (e.g. administrator, instructor, student, guest, guest speaker, teaching assistant, tutor, remote participants, etc.) creates a great deal of flexibility in how institutions use D2L.



Fig. 5. D2L-based RP Course

- New courses can easily be uploaded using the components feature, which includes the Export/Import/Copy tasks.
- Ability to define different organizational configurations in D2L allows different units (e.g. departments, institutions,

consortiums) to scale implementation of a single installation. This could allow all institutions in Tennessee to use a single installation of D2L.

- D2L “widgets” allow web content (e.g. RSS feeds, Google Searches) to be placed into courses.
- New email feature integrates campus mail (e.g. Outlook) into local emailing system.

MIT4450 RP course students have used the D2L online course materials and flexibly accessed the team discussions and various communication mechanisms in order to successfully accomplish their tasks in assessments and projects.

Laboratory practices have been arranged using the schedule tool available at the project website. Network cameras and audio connections helped both teams communicate effectively. Students having dial-up connections indicated their difficulties with the laboratory access capabilities, however high speed Internet connections have not faced any difficulties.

For the MIT4450 term project, teams have been formed with three-to-five students. One group has worked with a faculty member at WNC to rapid prototype a trebuchet. The trebuchet was designed by students in WNC-Engineering Design course. The WNC-Engineering Design instructor sent three pictures with details of the trebuchet to the TTU group. From these pictures MIT4450 group had to model the trebuchet on Pro/Engineer Wildfire software and then rapid prototype the trebuchet using the remotely accessible RP laboratory.

For the TTU team, the first step was to model the trebuchet using Pro/E software. Their first idea was to model the trebuchet out of one solid block. The trebuchet model looked great on the screen however, in the original design there was a pin that connected the stand with the throwing arm and making the model unable to move. The problem was an easy fix and the team quickly made the pin free-moving to allow the throwing arm to rotate.

After the prototyping process was completed there was yet again an obvious problem with the model. The pin was not strong enough to support the weight of the throwing arm and therefore would break. This was not the fault of the team design, but the material being used by the rapid prototyping system. The material used was not strong enough to support the weight of the throwing arm. On the actual trebuchet the material the pin is made of metal which is much stronger than the powder the rapid prototyping machine uses.

The final team solution to strengthen the pin was to rapid prototype the trebuchet in two

separate pieces, the stand being one, the throwing arm being the second, and then to attach the throwing arm to the stand with a small metal bar machined with a CNC technology. With this method the pin will be strong enough to support the throwing arm's weight resulting with a fully functional product.

The final step was to obtain price estimations for rapid prototyping the piece. If this design was rapid prototyped with a SLA or FDM process this possibly would have eliminated the need to create need for creating two separate parts because SLA or FMD would have had the strength and resolution to create one free moving assembly.

Student team has used Xpress3D [12] for price estimations on the stand and throwing arm. The price information, shipping date, process, company, and description of the technology were all investigated. The total price for the two pieces ranges from \$1,592 to \$4,144. The shipping times range from 2 to 8 days.

The details of the project works are shown in the YouTube presentations given in Figure 6.



Fig. 6. WNC RP Project in YouTube

In order to receive student responses, an IRB approved D2L survey instrument has been given to MIT4450 students. Sixteen students fully completed the survey leaving only two students were unable to participate in this study. Figure 7 reports the partial view of students' responses:



Figure 7: D2L Survey Findings (Partial)

Overall, the feedback received from the students was constructive and appreciative of the instructor's effort in course, remote laboratory and term projects. There was no major negative feedback or concern related to

the laboratory practices. Currently, the maximum limit of the remote access is 20 students into the remote connection. The only negative comments were on the connections.

VI. CONCLUSION

Remote laboratories are becoming more popular and these laboratories have various advantages in cost, time, maintenance and trained operator. TTU was able to convert its on-ground rapid prototyping laboratory into a remotely accessible format. Campus and remote students easily prototyped their parts with the help of an on-campus student assistant and received them in a short period of time. D2L tool was used for the instructional delivery of the online courses. The results of the D2L student survey reported that most of the students appreciated the distance delivery of rapid prototyping and they saved most of their laboratory and course hours since they used remote access features of the remote laboratory and D2L course management system. Newly developed RPIDS site is also a meeting place for industry, instructors and students. It allows educators to interact in every way possible with their students. It will also allow collaboration by teachers to promote the development of more resources for teaching and interaction. The RPIDS site is truly a resource for the advancement of RP.

VII. ACKNOWLEDGEMENTS

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VIII. LIST OF ACKRONYMS

- TTU: Tennessee Tech University
- NSF: National Science Foundation
- STEM: Science, Technology, Engineering, and Math
- D2L: Desire2Learn
- RP: Rapid Prototyping
- PHP: Post Hypertext Preprocessor

RPIDS: Rapid Prototyping Instructional
Delivery Support
ATE: Advanced Technological Education
CCLI: Course, Curriculum, and Laboratory
Improvement
MySQL: My Structured Query Language
NSDL: National Science Digital Library
WNC: Western Nevada College
SLA: Stereo-lithography-Apparatus (RP
technique)
FDM: Fused Deposition Modeling (RP
technique)
IRB: Institutional Review Board
FIE: Frontiers in Education Conference
ASEE: American Society for Engineering
Education
PI: Principal Investigator
STL: StereoLithography

NOTES

Parts of this paper were taken from the annual project reports and PI's FIE and ASEE conference publications. Dr. Isik worked in these projects as a postdoctoral research associate.

REFERENCES

- [1] <http://iweb.tntech.edu/rrpl>
- [2] <http://rpids.csc.tntech.edu/> or <http://rpids.net/>
- [3] <https://elearn.tntech.edu/>
- [4] http://rpids.csc.tntech.edu/moodle/CurrentDev/WebCT_RPIDS_Nov27_1522.zip
- [5] <http://www.rpids.net/moodle>
- [6] <http://iweb.tntech.edu/rpids/>
- [7] <http://www.nsd1.org/>
- [8] http://iweb.tntech.edu/rpids/2008_RP_Summit.htm
- [9] <http://home.att.net/~castleisland/>
- [10] <http://home.utah.edu/~asn8200/rapid.html>
- [11] <http://rpids.csc.tntech.edu/KnowBase.php>
- [12] <http://www.xpress3d.com/>