

A Proposal for an On-Line Library of Descriptive Geometry Problems

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Abstract. This paper describes an interactive system on the Internet, which implements an electronic library of Descriptive Geometry problems. All problems can be accessed as proposed exercises or solved problems (demonstrations). The library may register several alternative solutions for the same problem, allowing the user to choose the one he understands better. The system is implemented as a client-server architecture. The server side runs along with a web server and manages a database of problems and registered users. The client side is represented by a Java™ applet which provides graphical interaction with the users. Drawing tools are available for on-line problem solving. Demonstration of a solution is done through step-by-step animations and explanation texts. The system features some simple tutoring capabilities.

Key Words: Descriptive Geometry, Internet, Distance Learning, Digital Library
MSC 2000: 51N05

1. Introduction

Today, the Internet has a ubiquitous presence, reaching almost any place where a computer can be found [5]. Its exponential growing rate brings a lot of opportunities for many related areas. Education is one of them.

Distance learning, as an education method, has been available since the 18th century [3]. From that time to the early 1970's, it was primarily based on printed materials, characterizing the so-called 1st generation [4]. The 2nd generation witnessed the introduction of the radio, TV and telephone. Computer based tools characterize the 3rd generation. According to ARETIO [1] we are now living the second phase of the 3rd generation of distance learning

technologies, the virtual campus (networked multimedia workstations). Therefore, it is a recent development.

The only way we can exploit the full potential of the Internet on the education is by developing new tools, which capitalize on the interactivity provided by this medium. Graphical disciplines can be specially benefited.

In the 18th century, Gaspar MONGE (1746-1818), a French geometer, structured and developed a representation system called Descriptive Geometry (DG). Today, DG is the theoretical base for many important representation techniques. It provides a way to represent three-dimensional objects in a single plane (usually a paper sheet or the computer screen) and to solve spatial problems in these media. It is worth to note that, even with the widespread use of CAD systems, this theory still holds its importance not only for CAD developers but also for the users of this technology.

Besides its value as a 3D-problem solving tool and graphical representation technique, learning Descriptive Geometry is a proven method for developing spatial visualization skills, a very important ability for engineers, architects and every other professionals who design 3D forms.

Descriptive Geometry study is traditionally based on the execution of exercises. By studying solved problems the learner can both grasp solution strategies and understand how to perform operational procedures (e.g., rotation of a point about a line). Therefore, a library of exercises on Descriptive Geometry can be an exceptional asset to students of this subject. Furthermore, on the context of a distance learning environment, this resource acquires even more importance as it allows a student to quickly check many examples dealing with the same concept in case he can't fully understand it, making up for the absence of a teacher.

The on-line DG problem library described in this paper has some key features:

- it has both proposed and solved exercises (problems and examples). Commented solutions are available for all exercises in the library;
- it offers a tool for solving DG problems integrated in the on-line environment. This tool has an embedded automatic grading mechanism, allowing for instant feedback. User solutions can be archived and made available in the library catalogue;
- exercise resolutions are showed as step-by-step user-controlled animations along with textual explanations, respecting the learning pace of each individual student;
- as the library is completed and receives new contributions, we hope to provide several different solutions for each exercise. This feature allows each student to pick the option that seems to be the more logical or straight forward for her to understand;
- besides being a repository of exercises, the system has some tutoring capabilities;
- a simple student model of each library user is maintained allowing the use of some heuristics for suggesting an appropriate exercise when needed;
- the system collects user and exercise statistics, which can help diagnose individual or class difficulties.

The system described in this work is based on a client-server architecture, following a very modern approach. On the server side, a database keeps information about the users registered on the system and all the data about exercises and their solutions. The client side is based on a standard web browser and implemented as a JavaTM [2] applet, and is responsible for all graphical interaction with the user.

In the next sections, both sides of this architecture are detailed.

2. Library server

Interaction with the On-line Library of DG Problems starts when the user accesses the homepage of the system on the WWW. In that web page, if the user was previously registered, he can identify himself to the system (login name / password) or to register otherwise. Login date and time are logged. Besides a couple of demo exercises, no other resource can be accessed by non-registered users. This is to promote user contribution to the library, allowing new solutions or proposed problems to be added in its catalogue.

All the contributions (new problems or alternative solutions) added to the library are acknowledged with the login name of the contributor.

2.1. User registration

Registration is free of charge, as is the use of the system. Besides entering basic personal data (name, sex, age, institution, city, state, country and e-mail) the user can choose a class code (previously registered with the library administrator by another user, possibly his teacher) for grouping purposes. This feature allows a teacher easily get statistics about a class under his supervision or on any individual student assigned a class code he registered (see Section 2.5).

All user activity in the library system is logged for statistic and tutoring purposes, as explained in next sections. The user personal data are used only statistically and for research purposes.

2.2. Tutoring

After logging in, the user is greeted by the system, which suggests him a problem to be solved. This problem is chosen for that particular user and occasion. The heuristics behind this choice are based on both a preset sequence of topics and the available user records regarding all previous exercises he tried to solve and his corresponding performance. The adopted teaching strategy is very simple: the student must progress through a sequence of topics, successfully completing the exercises proposed by the system. In case of failure, another exercise on the same topic is presented to the user until he is able to solve one of them. Having demonstrated to the system that he learned the topic, the user is allowed to go on to the next one in the sequence.

In spite of the system's tutoring action, the user is able to request and see the resolution of any exercise in the library. Nevertheless, as mentioned before, every user action is recorded and, using this information, the system:

- never asks a user to solve again a problem he has successfully solved before;
- do not accept the correct resolution of an exercise as a valid proof of knowledge, if the user has had access to its solution before.

2.3. Library search

Besides the exercise offered by the library tutoring agent, the user may want to look for another exercises or solutions stored in the system. Library search can be performed by the following methods:

- browse by subject/topic;
- browse by estimated exercise difficulty;

- search for a keyword in the exercise title.

2.3.1. Browsing by subject/topic

In this mode, the user is presented with a hierarchical list of topics or subjects that looks like the one used in the Yahoo! portal (www.yahoo.com).

Examples of subtopics in the Descriptive Geometry theme are: true size, line view, point view, applications, pertinence, intersections, fundamental concepts, parallel lines and planes, rotations, etc.

The user can select a problem and try to solve it or request the list of alternative solutions available in the library catalogue.

2.3.2. Browsing by estimated exercise difficulty

The original author of an exercise can initially suggest its estimated difficulty level. The system is allowed to make its own initial difficulty estimation based on the number of steps and elements (lines, points, arcs, etc.) contained in the solution of an exercise. This estimation is continuously refined by considering the average grade the users got when tried to solve the exercise and also the average elapsed solving time.

The system prepares and presents a page containing a list of exercises ordered by estimated difficulty and subject.

2.4. Exercise/Solution Download

The download of an exercise is as simple as clicking on its title which appears in a table of problems. This action loads a web page containing basic information about the exercise and the applet interface appears in a new pop-up window. This applet will allow to user to solve the problem or go through a demonstration of each step of the solution.

One aspect of particular relevance in the Library conception is the fact it stores several different solutions for the same exercise. It is a very common fact in class, a student to understand more easily the solution proposed by a colleague than the one offered by the teacher. These alternative - but correct - solutions should be collected as they are valuable teaching resources. Furthermore, availability of a variety of solutions allows learning of diversified solving strategies and techniques.

2.5. Statistics

The library system maintains the following statistics regarding exercises:

- number of downloads of each problem;
- number of downloads of each solution;
- response ratio for each problem;
- mean elapsed solving time;
- success ratio for each proposed exercise;
- estimated difficulty and
- the same statistics above grouped by exercise topic.

For each individual user, the following information is saved:

- which proposed exercises the user downloaded and when (date/time) he did it;
- which solutions were requested by the user and when (date/time) he did it;

- resolution script files sent back by the user and corresponding outcomes (grading) and elapsed solving time;
- total and topic average grades.

Any user is able to see statistics regarding exercises and his/her own performance on problem solving.

The original creator/requester of a class code is supposed to be the instructor of all users registered under that code and therefore is allowed to access all the statistics for those users as well as those for the class as a whole.

3. Client applet

A single JavaTM applet and the user's browser form all the system's client side. This applet is based on earlier works by the author [6, 7] and was adapted to the subject of Descriptive Geometry.

The main function of this applet is to serve as a graphical tool for:

- demonstrating the resolution of exercises;
- allowing the user to create and solve a new exercise;
- allowing the user to solve a proposed exercise and check her solution.

For each of the three functions above the applet has a special operation mode, described in the next sections. The operation mode is set by an applet parameter (inserted in the HTML page code).

Although inserted in an web page, the applet runs on its own window, allowing the user to position it anywhere in the screen and resize it to accommodate all the elements in the drawing.

In its present version, this applet is implemented according to Java specification 1.0, allowing it to run even in older browsers. Its total size is less than 70 Kbytes allowing fast download.

3.1. Solved exercise mode

The Solved Exercise Mode is used for viewing a step-by-step animation of the solution of a Descriptive Geometry problem.

In this mode of operation, the applet presents a very simple user interface, consisting of only three VCR-like buttons (Next step, Back, Restart) which control the animation pace (Fig. 1). In the bottom of the applet window, a text area shows an explanation for the current step.

A fourth button may be present to turn on and off the audio narration of the explanation, if available.

3.2. Problem Mode

When operating in the Problem Mode, the applet presents a user interface featuring a toolbar on the right side and a message area in the bottom (Fig. 2). Some of the functions available are: visualization (pan, zoom, and grid), drawing (lines, points, and arcs), and labeling as well as control of the explanation steps and text.

The student uses these tools to solve an exercise. She should divide the resolution in steps and write a comment/explanation about each one. When finished, she must select the

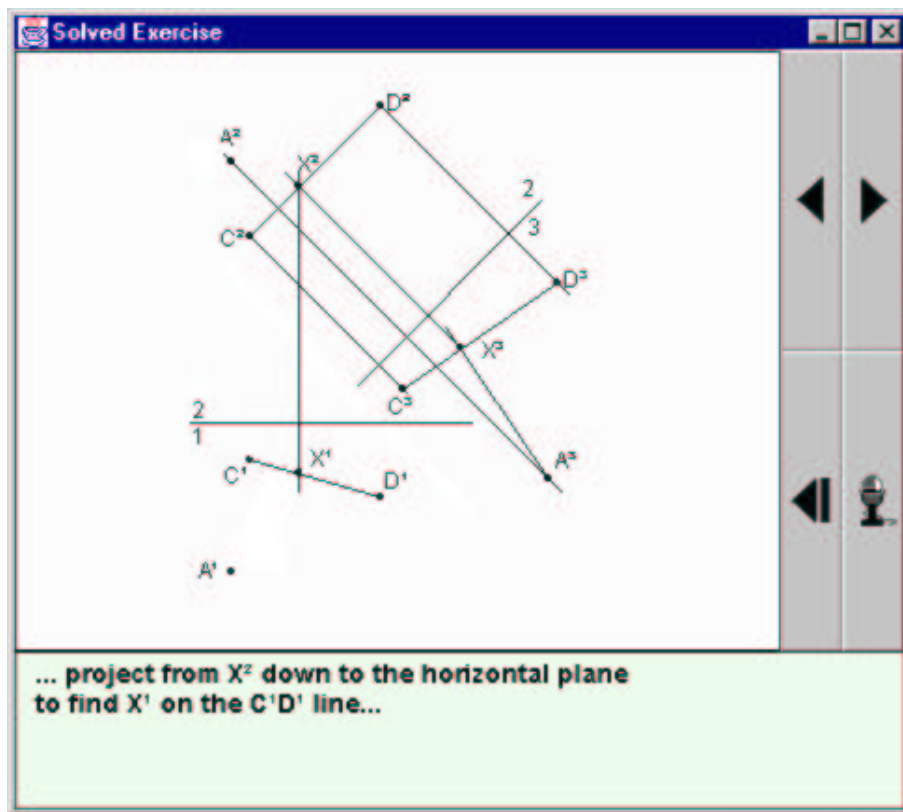


Figure 1: Client applet in Solved Exercise Mode

elements that make up the solution of the problem and click on the “check/solution” button to get an immediate feedback regarding the correctness of her answer. The correct answer for the exercise is always stored in the script file for this problem, which was download by the applet on start-up. The applet uses this information to check the student’s solution.

New solutions to an exercise can be contributed to the library using the applet in the Problem Mode. After trying to solve the problem, the student can store his solution in the library server by clicking on the “script” button. His solution will be put in a special queue to be reviewed by the library administrator who will, if it is the case, incorporate it as a new alternative solution to the problem. This user’s instructor or teacher (the one who registered the class code of the contributing student) has access to all his students’ solutions, which are waiting in this queue.

3.3. Create exercise mode

This is the way anyone can contribute an exercise to the library. The submitted exercises are stored in a queue waiting to be reviewed by the library administrator before the definitive incorporation in the library catalogue.

The interface in this mode is the same as in the Problem mode. The main differences are:

- the applet starts with a completely blank area;
- the “check/solution” button is used to record the solution of the proposed problem instead of checking it.

The script button is used to send it to the Library Server for approval. Once inserted on the library catalogue, the problem author’s name is showed along with the exercise.

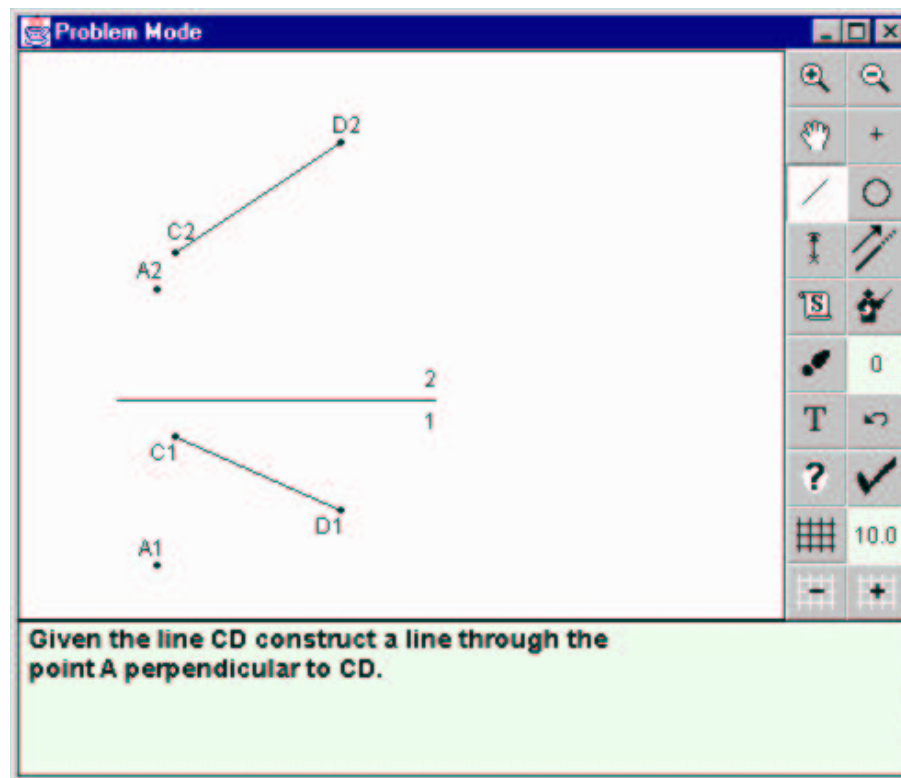


Figure 2: Client applet in Problem Mode

4. Conclusions

This paper presented an interactive on-line tutoring library of Descriptive Geometry exercises.

By the time of this writing, the library system is not fully operational yet. As the system goes on-line, it will be open for free use and contribution by the international community and will be divulged through the appropriate channels. Please, contact the first author for definitive web site address.

Only individual exercises were tested with students. The general response was very good. Students seem to enjoy this mode of learning. Our engineering students like to interact with graphical applications on the web. This is especially important for motivating engineering freshman on their first contact with Descriptive Geometry and decrease drop-out rates.

A methodological investigation on the level of learning achieved by the use of this resource is yet to be done.

The system will support multiple languages. Portuguese, Spanish and English versions are planned. Again, we count on community cooperation to release it in new languages.

Acknowledgments

The authors would like to thank the Pró-Reitorias de Graduação and Pós-Graduação of the University of São Paulo and FAPESP – Fundação para o Amparo da Pesquisa do Estado de São Paulo, Brazil, for partially funding this project. Daniel B. GARCIA collaborated on the implementation of the applet.

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Received August 1, 2000; final form June 26, 2001