CAI Platform for Fundamental Geometric Training on Perspective Sketching

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Abstract. For most designers, freehand sketching is the primary tool for conceptualization in the early stage of the design process. However, existing education programs on concept presentation techniques rarely emphasizes the practicing of two most fundamental geometric shapes - cube and cylinder. Lack of correct reference and proper training, students often end up with disproportioned sketches that deviate from common visual experience which would lead to misunderstanding of original design.This research developed a computer-assisted cube sketching instruction platform for novice, with which users can practice correct cube sketching using freehand skills or digital devices for self-improvement. This platform can provide instant corrective feedback and demonstrated 19% sketch accuracy increased relative to the control group in a series of experiments. Based on the successful experience, a cylinder training program is under development. The ultimate goal of which is to develop a comprehensive CAI platform to help novice improve their skills by self learning and correction.

Keywords: CAI, Perspective sketching, Self-instruction, Geometric sketch practice.

1 Introduction

Freehand sketching has long been recognized as an indispensible element in product design and development. Sketches can provide the designers with visual clues that inspire creative inventions, generate new information, and expand mental imagery(Goldschmidt, 1991, 1994). Akin in his 1978 article pointed out that sketches can help designers adjust and synthesize ideas in the problems solving process. In fact, sketches facilitate the visual search among alternative options and the exploration of design concepts.

In a common instructional curriculum for sketching, students often starts with simple but fundamental geometric units before developing the sketching skills for complex shapes (Henton, 1980). Each and every complex shape can be treated as dissected or stacked cubes (Liu, 1997). Therefore, the cube is the most fundamental shape in design. Errors of perspective cube sketching can be broken into 7 types: 1) askew vertical line, 2) anti-perspective, 3) askew horizontal line, 4) beyond cone of

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vision, 5) excessive vanishing points, 6) proportion maladjustment, and 7) vanishing lines in parallel (Luh and Yang, 2002).

However, the lack of an accurate mechanism for inspecting student sketches and providing a geometrically correct solution as reference means that even instructors and professional designers can only correct and offer suggestions to their students based on their experiences. Discrepancies between such feedbacks and truly accurate solutions cannot be readily determined unless the sketches are inspected individually using the perspective principle.

Most existing sketch related CAI systems research focus on fundamental knowledge instruction including basic perspective, two point perspective, light-shadow perspective, and geometry perspective(Wu, 1998；Hong, 2000； Lin, 2004；Lin, 2004). These systems often concentrate on repetitive and fixed materials so the students can study the knowledge-based subjects after school, and find textbook solutions in standardized databases. Such CAI systems provide learning opportunities unconstrained by time or space, and can therefore provide substantial educational assistance where resources are severely lacking.

Motivated by the fundamental relationship between freehand sketching and perspective as well as CAI systems' potential to achieve active learning and compensate for limitations in educational resources, this research identifies the specific needs of sketch learning and incorporates them into a software instruction system. The resulting product utilizes two point perspective as the fundamental principal, focuses on the cubic shape as its subject, and demonstrates the ability to inspect and offer revision suggestions to users' sketches, thus providing real-time error detection and customized feedback to assist users in self-directed active learning.

2 Reversed Perspective Approach

The basic components of foot-point approach two-point perspective drawing includes (Figure 1): from the top view, the location of picture line (PL) (to simplify, PL in the

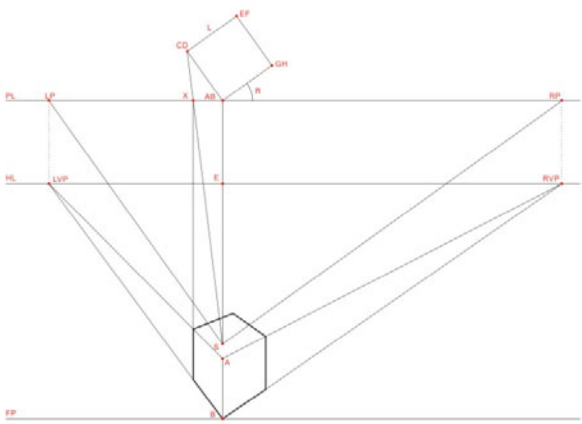


Fig. 1. The foot-point approach two-point perspective

figure is aligned with the front edge of the unit to maintain its actual length), unit length (L), rotation angle (R), station point (S), and the length between PL and the viewer (segment length of SA); from the side view, the locations of the horizontal line (HL) and foot-point (FP), and the distance between the object and the viewer's eye (E) or foot-point (in this case the unit is placed on the ground).

In accordance with the above drawing information, reversed drawing process (Figure 2) is listed as follows:

1. Extend perspective line to obtain vanishing point (LVP). From point LVP, draw horizontal line HL perpendicular to the front vertical line AB; extending line bh results in the vanishing point on the other side (RVP).
2. The cone of vision can be defined by drawing a circle with a radius of half the length between two vanishing points. The station point (S) can be identified by extending the front vertical line AB to the circle of the cone of vision.
3. If there exists a picture line (PL) which is parallel to the horizontal line HL, the front vertical line AB extension intersects with the picture line PL at point X. Draw two line segments XY and XW, with lengths identical to that of line AB, parallel to line SRVP and line SLVP respectively.
4. Extend line CD to intersect with PL at point J; draw line WJ to intersect line AB at the standing point (SP)
5. Line SPY intersects with picture line PL at point K. The vertical line of point K intersects with line BH at point H', which is the correct location of point H. Follow the same method to define the correct location of point G.
6. The intersection of line G'RVP and line CLVP is the correct location of point E, while the intersection of line DRVP and line H'LVP is the correct location of point F.

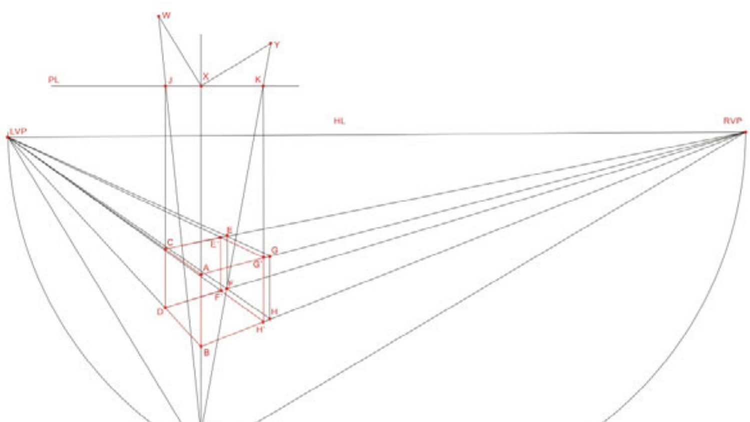


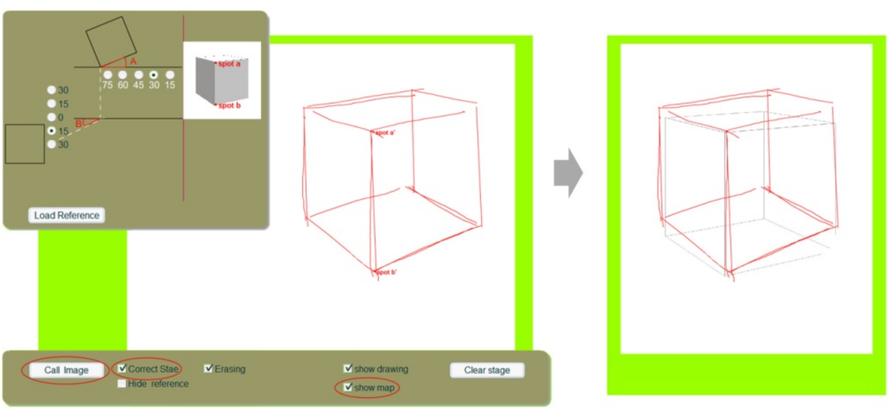
Fig. 2. The reversed two-point perspective approach

3 System Components and Interface

3.1 Introductory Training Program

The development principle for this program is “Observe and memorize.” By providing a verity of reference images for the user to observe and sketch, this program develops the user’s observation, hand-eye coordination, and visualization ability for cube sketching. Based on the cone of vision, the program offers five horizontal rotation angles (15, 30, 45, 60, and 75) and five vertical rotation angles (30, 15, 0, -15, and -30), for a total of 25 three-dimensional views of an orthogonal cube. This helps the user develop accurate spatial understanding of a cube.

After starting the introductory training program, the user can choose the cube he or she wants to practice with, specified by the horizontal rotation angle A and vertical rotation angle B, from the upper left-hand corner of the reference image panel. Clicking on “Load Reference” would bring up the chosen cube to the right-hand field. The user can also hide the reference image by checking “Hide Reference”; this can test the user’s memory, visualization, and understanding of the cube. Based on personal preference, the user can choose the input method (digital pen or conventional pen) to sketch the chosen cube in the specified field. After sketching the cube, the user can compare the sketch with the correct solution by checking “Correct State” and clicking on the reference vertices of the sketch and the reference image (i.e., points A and B and points a and b in Figure 3(a)). If the user clicks on “Call Image” when “Show Map” is checked, the correct solution and the freehand sketch would then superimpose on one another for comparison and correction (Figure 3(b)). After making corrections, the user can then click on “Clear Stage” to clear the image for the next training lesson.



(a) (b)

Fig. 3. The operating interface of the introductory training program: (a) input the reference vertices of the sketch and the reference image; and (b) the superimposition of the correct solution and the freehand sketch

3.2 Advanced Revision Program

The development principle for this program is “Visualize and Verify.” The user can specify the perspective angle of the cube, let the system detect and point out errors, and construct accurate images as references. The objective is to enhance the user’s accuracy in sketching cubes from imagination.

After starting the Perspective Practice revision program (Figure 4, left), the user can first adjust the error tolerance based on his or her skill level or need. This can be done by adjusting X (askew angle of the vertical line), Y (tilt angle of the horizontal line), and Z (vanishing line error quotient). The user can then sketch a cube from imagination onto the drawing field, and check “Locating Spot” to mark the eight reference vertices (Figure 4, middle) before clicking on “Correcting.” The program would then identify errors with red lines and/or descriptions, and offer revision suggestions/instructions in the yellow “System Message” box on the right-hand corner of the screen. The user can also check “Hide Message” to practice his or her ability to identify errors without assistance. After inspecting the sketch, the user can click on “Clear Stage” to clear the image and decide whether to adjust any program setting. The process can be repeated until the user makes no error outside of the specified error tolerance.

Once the sketch passes error inspection, the user can click on “Re-standardize” to reveal the correct solution superimposed in blue lines (Figure 4, right) for detailed comparison and further modification. Finally, the “Calculate” function allows the user to calculate the area of the sketched cube, and the percentage of sketching error. The user can save the data for future reference or analysis by clicking on “Save Data.”

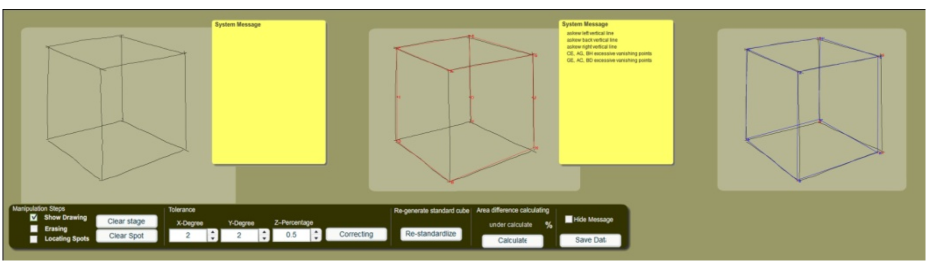


Fig. 4. The operating interface of the advanced revision program: Advanced program setting options; reference vertices marking and revision instructions; superimposition of the correct solution shown in blue

4 System Effectiveness

This study analyzed the Experimental Group’s drawing ability before and after the experiment. The percentages of error were summed up into cumulative percentage of error, and both cumulative percentage of error and percentage of accuracy pre- and post-experiment were compared through Paired-Samples T Test. As summarized in Table 1, both cumulative percentage of error and percentage of accuracy were significantly improved (Sig. < 0.05), indicating that the CAI system is effective in reducing students' errors in sketching cubes. Comparing the percentages of accuracy pre- and post-experiment (0.15 and 0.34, respectively), the study showed that this CAI system improved sketching accuracy by 19%.

Table 1. Experimental Group's cumulative percentage of error and percentage of accuracy before and after the experiment

		Average	t	Sig. (2-tailed)
Cumulative percentage of error	Pre-experiment	2.07	-3.336	0.004
	Post-experiment	1.17		
Percentage of accuracy	Pre-experiment	0.15	-2.579	0.020
	Post-experiment	0.34		

5 Conclusions and Suggestions

The current research develops a computer-assisted instruction (CAI) system based on foot-point approach two-point perspective. The system is capable of identifying sketching errors and providing revision suggestions, and the teaching experiment has arrived at the following three conclusions:

1. This research has developed a CAI system suitable for technical training; the system can provide correct reference solutions and revision suggestions, enabling effective learning through the system.
2. This system employed reversed perspective approach to derive technical drawing from perspective drawings, and subsequently reconstructs correct perspective reference solutions for users to compare and revise their sketches. Experimental results demonstrated the feasibility and effectiveness of this approach.
3. When the CAI system developed in this study was tested in a learning experiment, the Experimental Group improved sketching accuracy by 19% (2.35-fold higher than the pre-experiment accuracy), and demonstrated significant improvement compared to the Control Group.

This study is an initial attempt to develop a CAI sketching system and determined its feasibility, practicality, and effectiveness in technical education. As such, the system developed in this study focuses on the training of two-point perspective cube sketching. To advance this effort, the program can be expanded in the future to include cylindrical, conical, pyramidal, and other geometric shapes, making the training system more comprehensive, and effectively enhance the program's function and the users' learning experience.

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