A Digital Training System for Freehand Sketch Practice

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Abstract. Freehand sketch is a fast and easy tool for idea development and communication, especially in the critical front-end or predevelopment stages. While it is important to any designer, lacking of appropriate mechanism for correction in fundamental design education makes even professionals hard to precisely handle accuracy of perspective sketch. Based on two-point perspective method and using cubic shape as subject, this research develops reverse drawing approach and accordingly establishes a digital training system for freehand sketch practice, namely Perspective Practice. Users can operate conventional pen and paper for input and the system automatically illustrates on screen a correct perspective drawing on top of the sketch done by the user, pointing out the concept or technique for improvement. The system provides users with ways in understanding their current skills and guidelines for improvement, through which the efficacy in digital technical training can be enhanced.

Keywords: freehand sketch, perspective drawing, reverse drawing method, digital training.

1 Background and Goal

Freehand sketch is a basic skill to any industrial designer and a fast and easy tool or media for idea development and communication. Through sketches or 3D perspective, designers are able to interact with inspiration, to record, compare, organize, and improve their ideas towards new product concepts. Through sketches, designers are able to discuss with clients and exchange ideas with engineers more effectively and efficiently to improve product design and to facilitate new product development process. With swift advancement of computer technology, many conventional tools for creative development and communication have been replaced by system software. This is particularly obvious in downstream processes when concerned information is clearly defined. In front-end development stages, characterized by high degree of

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uncertainty, computer system is hard to do anything and sketching remains a key competence.

Sketch ability is viewed as one key factor for recruiting designers by almost all design managers. There is a strong link between one's sketch ability and one's creativity or imagination of the future. While important, sketch training has been lacking of quality control mechanism in fundamental design education. Because of that, many professional designers remain suffering from poor perspective sketches, including perspective errors, inconsistence between perspective sketching and engineering drawing, askew horizon line, to name a few. Major causes are three:

1. High teaching load in related courses. Averagely, one teacher instructs 30 to 40 design students in presentation techniques or perspective drawing class. With very limited time for each student, individual errors are hard to be completely corrected.
2. Students are trained to undertake creative works in the future, and so they are often required to practice work without firm answer. When a student has problems in perspective sketching, the problems can hardly be identified and corrected by one self, nor can they be instructed by peers, senior students, or even the teacher.
3. Perspective sketch bases on visual recognition, not on mathematical precision. Thus, it is difficult to develop objective measures for improvement.

Among the above causes, if the third one can be effectively managed, then the rest can be eased accordingly. With an emphasis on the third cause, this research develops needy theories and system tools for digital training and measures for correction, which may reduce reliance of teacher's instruction effort on the student's basic practice while increasing opportunity for self-training, enhancing efficacy in digital learning.

Perspective methods can be categorized into three approaches: one-point, two-point, and three-point. Due to various needs of professional work, designers with different backgrounds adopt different approaches. The one-point method is commonly used by interior designers, two-point approach by industrial designers, and three-point process by architects and urban designers. Relatively, two-point method has merits of extensive applicability and being easier to learn, and thus widely adopted by product designers. It is therefore concentrated in this research.

Perspectives deal with cognition of 3D space, in which shapes distort and the quality and quantity of firm information for interpretation are insufficient. Hence, it is hard to establish the intended system in accordance with individual points in the space. Exercise of cubic shape is fundamental to all design students. Based on practice of cubic shape, concerned theories and procedures are developed.

To date, pen and paper are still used as major tools for sketching by most designers for many reasons, high availability, low cost, no need of electricity, among others. The system to be developed- Perspective Practice- employs conventional pen and paper as input device and user interface. Through standard digital equipment Intous 3 by Wacom, perspective sketch is drawn on paper and at the same time automatically input into the system for further computation, comparison and correction. Based on locations of key points on the sketch and through the reverse drawing method to be introduced in latter section, the system defines all critical information for a correct perspective sketch and redraws a correct one on its top, pointing out error types made by the learner and suggesting useful guidelines for refinement.

2 CAS and CAI Systems

With advancements of CAD, AI, pattern recognition and related technologies, computer aided sketch (CAS) has become a research focus [6]. CAS concerns design behavior, interaction between object in construction and thinking process in mind, among others. Although claimed to put an emphasis on design concerns, it essentially deals with engineering issues to date. Most CAS systems, such as Viking [7], and algorithms employed in CAD systems [8] adopt parallel perspective as analytical element, which is a drawing tool or language for engineers, not for product designers. Most product designers are trained to first draw 3D perspectives to meet customers' needs in visual perception, form recognition and product aesthetics, and then interpret them into engineering drawing for communication with engineers and NPD work partners. The quality of their 3D perspectives largely determines the fate of a new product idea in development. In light of its importance, designer's drawing quality issue is targeted in this research.

Literature survey reveals that existing computer aided instruction (CAI) systems for perspective sketch mainly function to demonstrate construction of perspective drawing. [1], [2], [3], [4]. These systems are essentially electronic version of textbooks, merely instructing users how to construct a 3D perspective. Functions that help students to identify their error types and to correct and enhance their sketch skills have not been developed yet. If such mechanisms can be implemented, students can train and improve all by themselves, which makes digital learning on technical skills more effective and efficient.

Since there is no closely related system for reference, this research intends to develop one that bases on two-point drawing method for training basic 3D perspective sketch skill, using cubic shape as exercise subject.

3 Foot-Point Method and Its Required Information

There are two ways in construction of two-point perspective drawing: foot-point and measure-point approaches. In this paper, the former method is adopted. For successful exercise, the following information is required (Fig. 1): from top view, picture line (PL) location (for easy drawing, PL is aligned with front corner of the square in order to have an actual length for use later on), side length (L) and rotated angle (R) of the square, and station point (S) location, i.e., the length between PL and drawer or viewer (segment length of SA or SB); from side view, horizon line (HL) location, foot-point (FP) location, and length between object and viewer's eye (E) or foot (in this case the cube is placed on the ground). Since foot-point approach is fundamental to students of engineering colleges and design schools, detailed drawing procedures are not introduced herein.

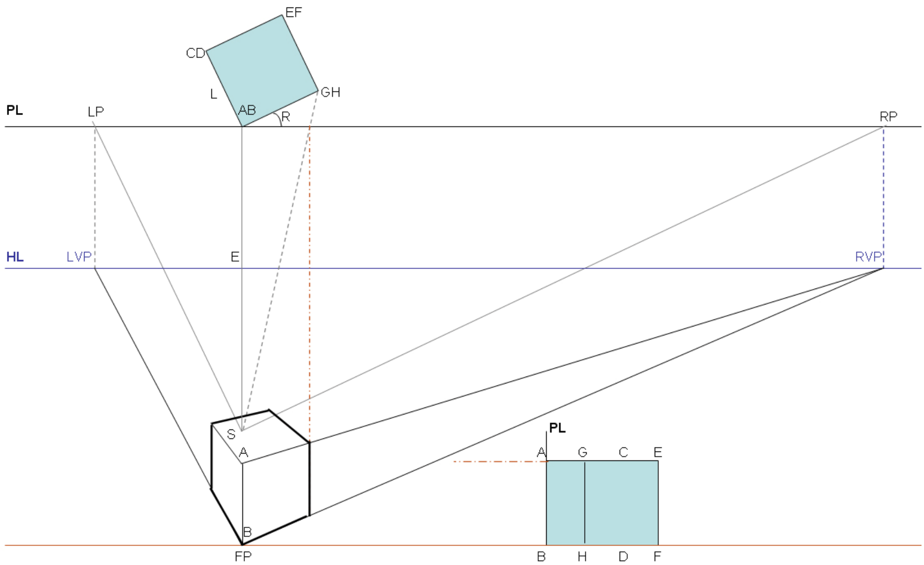


Fig. 1. Foot-Point Approach and its Required Information

Error types in perspective sketching of cubic shapes are (Table 1): vanishing lines in parallel, excessive vanishing points, anti-perspective, proportion maladjustment, askew center line of vision, askew horizon line, and beyond cone of vision [5]. Methods for detecting perspective errors or guidelines for improvement include (Table 2): slope analysis, minimal angle, inclusive circle, and back side comparison. Based on the above information, the system checks on perspective quality and identifies error types and provides guidelines for improvement. Precision is hard to achieve in freehand sketch. Tolerance should thus be a design factor. In accordance with visual capability, a threshold of ±2° is applied to any line drawing for viable perspective sketch of cubic shape.

4 Perspective Practice System

Following due perspective drawing methods, a viable 3D cubic shape can be obtained in accordance with its engineering drawing. By reversing the drawing process, key elements for correction of a cubic shape sketch can be defined. Accordingly, error types of the sketch and suggestions for improvement can be made.

The new system consists of two components- basic exercise and advance refinement- of which details are elaborated as follows:

Table 1. Error Types in 3D Perspective drawing

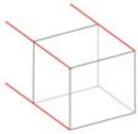
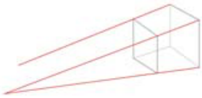
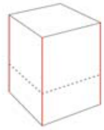
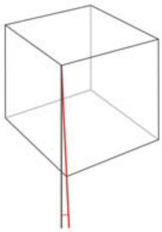
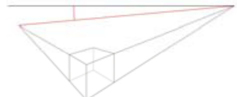
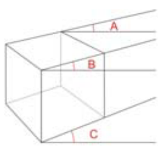
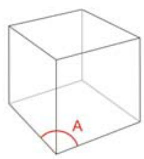
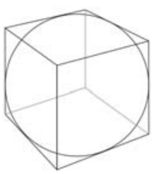
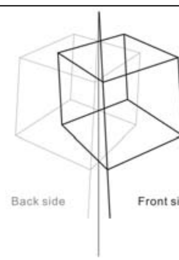
(1) vanishing lines in parallel		(5) excessive vanishing points	
(2) anti-perspective		(6) proportion maladjustment	
(3) askew center line of vision		(7) askew horizon line	
(4) beyond cone of vision			

Table 2. Methods for Perspective Check

(1) slope analysis	 A< B< C	(3) minimal angle	 90°< A
(2) inclusive circle	 Roughly include a circle	(4) back side comparison	

4.1 Basic Exercise Component

This component allows user to choose a cubic shape in space from selected angles (in top view, rotation angles from 15° to 75° with an increment of 15°; in side view, from -30° to +30° due to constraint of the cone of vision) for exercising perspective sketching (Fig. 2). Through the pen-paper-Intous 3 interface, the sketch and the chosen shape are overlapped for comparison and correction. The main functions are three folds: (1) to train the user to memorize certain cubic perspectives for easy application, (2) to let the user understand the error types one often makes, and (3) to enhance the user's freehand technique to an acceptable level for further refinement.

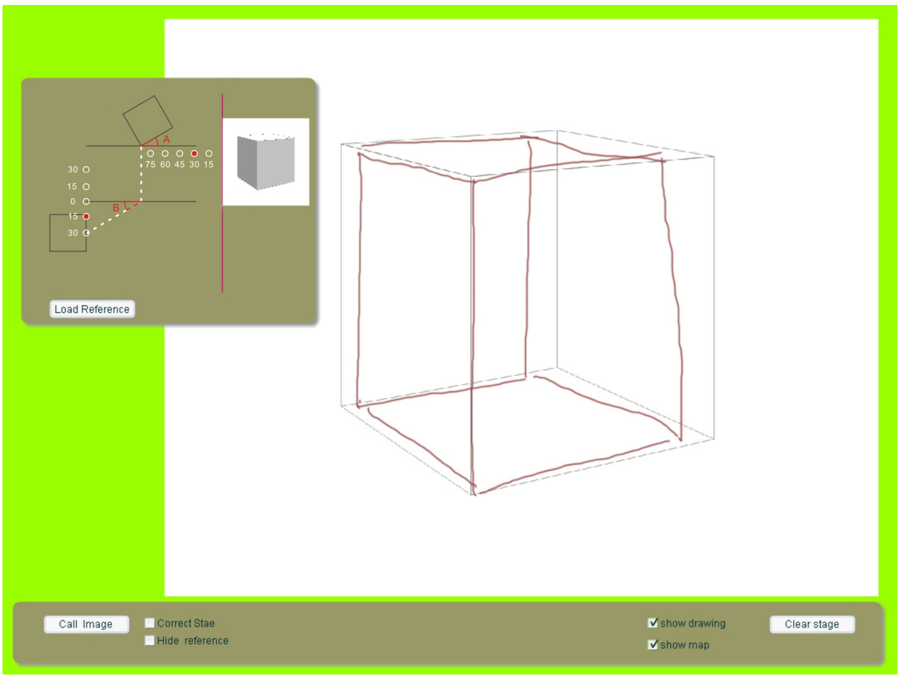


Fig. 2. Illustration of the Basic Exercise Component

Based on the following rules, the system identifies and shows the error types that users make:

1. If any vertical line is tilted more than ±2°, then the system shows the vertical line in red and display "askew vertical line."
2. If length of the central vertical line is shorter than any of the vertical lines on two sides, then the system displays "anti-perspective."
3. If length of the central vertical line is equal to any of the vertical lines on two sides, then the system displays "vanishing lines in parallel."
4. If horizon line is tilted more than ±2°, then the system displays "askew horizon line."

5. If included angle between the two lines on the top or at the bottom is less than 90°, then the system displays "beyond cone of vision."
6. In each set of perspective lines in parallel, have the one in the middle as center line and the corner point where the center line passes through as base point, if the center line intersects with the other two lines at different points and the ratio of the length from the base point to the first intersection to that to the second intersection is less than 0.85, then the system displays "excessive vanishing points"
7. If length of the central vertical line is greater then the distance between those on the sides, then the system displays "thin cube" or "proportion maladjustment."
8. If length of the central vertical line is shorter than any other non-vertical line, then the system displays "flat cube" or "proportion maladjustment."

4.2 Advanced Refinement Component

Through the basic exercise component, a viable cubic shape is ready for further refinement. Based on 6 reference points (a, b, c, d, g, h) on the sketch cube (Figure 5), the system defines center of vision (CV) line (line ab), datum line (either line bd or line bh) and datum plane (left side or right side of the cube) for interpretation of a correct answer. A qualified datum plane must meet the following requirements: it should be the one that with shorter length from CV line to the vertical line of its far side, and that its upper and lower perspective lines form an acceptable vanishing point. When one side plane is defined as datum plane, the lower perspective line of the other side plane is defined as datum line. (Fig. 3)

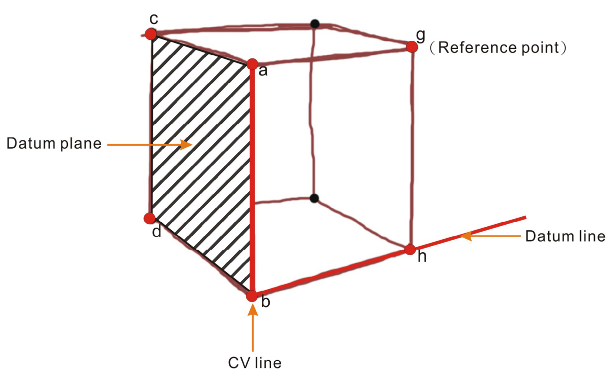


Fig. 3. Reference Points, CV line, and Datum Line and Plane for Advanced Refinement

In accordance with the above drawing information and based on the following "reverse" drawing process (Fig. 4), the system redraws a correct cube superimposing up on the sketch cube for comparison and further refinement of one's sketch skill. (Fig. 5)

1. Have CV line ab as vertical axis and get one vanishing point (LVP) from the datum plane. From point LVP, draw horizon line HL which is perpendicular to CV line, by extending datum line bh begets the vanishing point on the other side (RVP).
2. The cone of vision can be defined by drawing a circle at the center point (o) of the vanishing points with a radius of half of the length between two vanishing points. The station point (s) can be identified by extending CV line to the circle of the cone of vision.
3. Provided that there exists a picture line (PL) which is in parallel to horizon line HL. The CV line extension intersects with the picture line PL at point x. Respectively parallel to line sRVP and line sLVP, draw two line segments xy and xw, of which lengths are identical to that of line ab.
4. Extend line cd to intersect with PL at point j, draw line wj to intersect line ab at 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', where is the correct location of point h. Follow the same method to define the correct location of point g.
6. At intersect of line cRVP and line g'LVP is the correct location of point e.

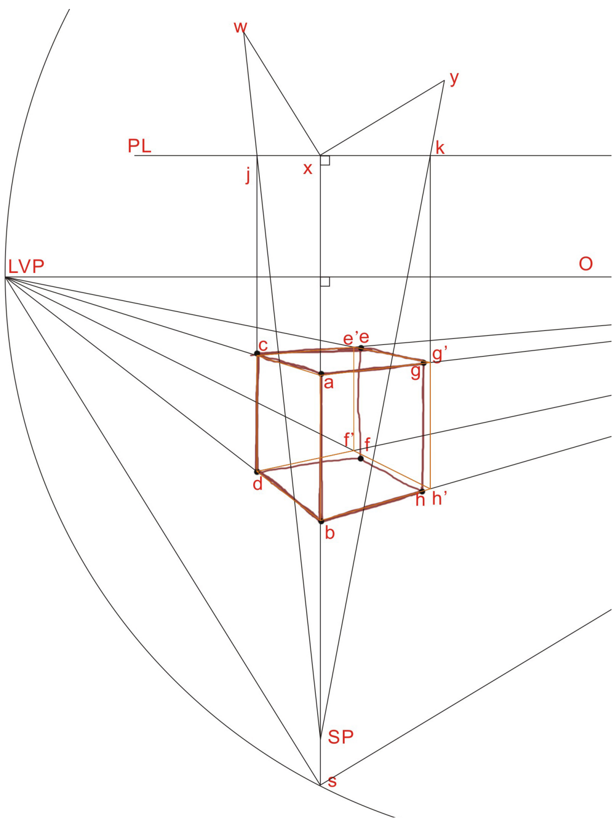


Fig. 4. Reverse Drawing Process for Perspective Construction

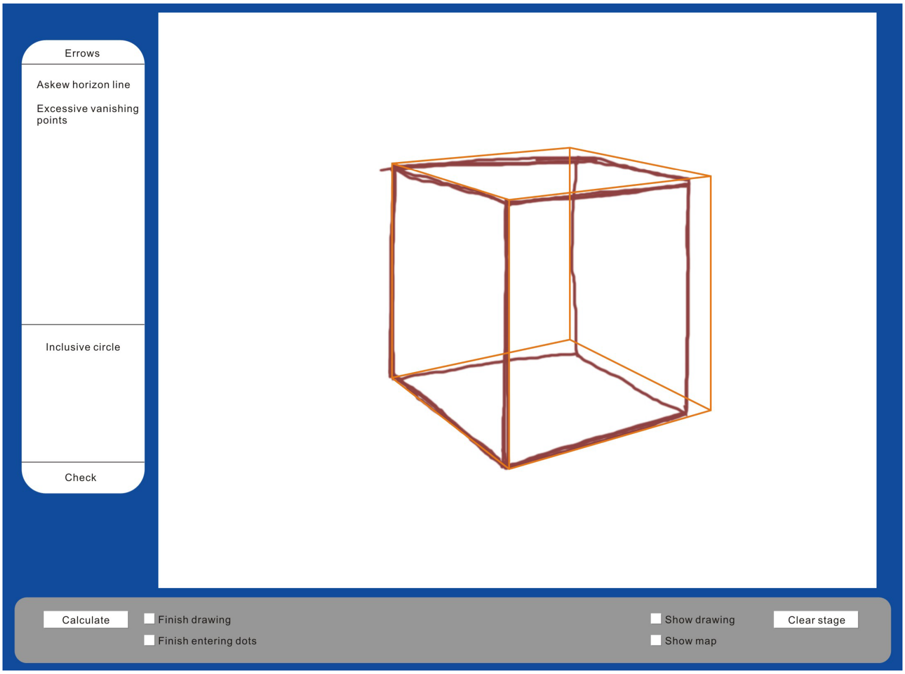


Fig. 5. Illustration of the Advanced refinement component

5 Conclusions and Suggestions

Based on visual recognition and the reverse perspective drawing process, the Perspective Practice system is developed for digital training of perspective sketching. It consists of two components, one for enhancing basic skill and another for further refinement. With this system, students have right answers for exercise and their basic skills can be enhanced efficiently and effectively. Current accomplishments are as follows:

1. The system is practical and useful for digital training of basic perspective skill.
2. With this system, users can examine the error type most frequently made and accordingly improve their concepts and techniques.
3. The reverse perspective drawing process is feasible and innovative.
4. In perspective space, each straight line may have its unique slope, through which the spatial relations among different lines can be clearly defined. This might provide a new solution to help ease the face recognition difficulty in computer aided sketch.

The usability and effectiveness of the new system will be tested in Presentation Techniques class, Spring semester of 2007, by students of Department of Industrial Design, National Cheng Kung University, Taiwan. Concerned statistical results will be presented at the conference.

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