Ongoing Research on Adaptive Layered Manufacturing from Overtraced Freehand Sketch

Natthavika Chansri and Pisut Koomsap[1]

Industrial and Manufacturing Engineering, Asian Institute of Technology, Thailand

Abstract. Freehand sketch on a paper is commonly seen being used as it is an effective convenient way to express rough ideas. The sketch is typically transformed to be a 3D CAD model by a designer for subsequent operations such as rapid prototyping process where a physical prototype is fabricated from a 3D CAD model. To speed up the realization of an idea, a research called adaptive layered manufacturing from overtraced freehand sketch has been being developed as an attempt to shorten steps from having a sketch drawing to obtaining a physical prototype. Presented in this paper is the current progress of the research. A single line drawing identification module is being developed to transform a paper-based overtraced freehand sketch to be a single line drawing. This module is required to generate more information about the sketch (i.e., the number of lines and their starting points and endpoints) since the initial information is limited to a batch of points. The algorithms developed for this module have been implemented on LabVIEW program. Some examples of sketch to a single line drawing transformation are also presented in this paper.

Keywords. Paper-based overtraced freehand sketch, single line drawing.

1 Introduction

Product design and development (PDD) is critical to the success of manufacturers, especially, in today's high competitive market where voice of customer is as important as manufacturer's capability. The trend of product development has changed from manufacturer-oriented to customer-oriented [1]. In the early days, tools and techniques limited manufacturer's capability to offer simple products. Advancement in technology has opened up a market. High competition has made voice of customer louder. It is arguable that the only way for the manufacturers to be competitive in the market is to adopt a customer-driven strategy [2]. Today, customer needs are even more sophisticate. They demand faster and better responsiveness [3]. The earlier introduction of a product creates momentum that could not only increase product's sales but also extend them much further into the

[1] Industrial and Manufacturing Engineering, School of Engineering and Technology, Asian Institute of Technology, Pathumthani 12120, Thailand, Tel: +66-2-5245678: Fax: +66-2-5245697; Email: pisut@ait.ac.th; http://www.ait.ac.th

J. Pokojski et al. (eds.), *New World Situation: New Directions in Concurrent Engineering*,
DOI: 10.1007/978-0-85729-024-3_2,

future. Therefore, goods and services must be met or exceeded customer expectation and delivered quickly.

Rapid prototyping (RP) has been introduced and become an important technology that allows designer-customer realize and experience their ideas rapidly. It can help reduce 30-50% of manufacturing time for product development [4]. RP is a technology for fabricating complicated physical prototype without molds and dies. A 3D CAD model is translated into a stack of 2D contours which are used to generate machine commands for constructing a prototype layer by layer. Typically, a rapid prototyping process starts with obtaining a 3D CAD model, which can be created on any CAD software. Since the data formats are different among the software, the created model will be converted to a common format, called Stereolithographic (STL) file. The STL model is then sliced, and based on these sliced layers, machine commands are generated to build a physical prototype layer by layer. Post processes may be required depended upon the selected RP technique.

Besides creating a 3D CAD model on commercial software, today's technologies make it happens for the 3D CAD model to be created from its physical object as well as engineering drawing when they are available. Manufacturer can use reverse engineering, RE, to reconstruct a CAD model directly from a product that customer brings in, and by coupling RE with RP its physical prototype can be delivered back to customer in a short period of time. Several researchers have tried to improve and to realign steps in both processes to make their direct integration work more effectively [5-6]. The similar idea has been extended to reconstruction a physical prototype directly from orthographic views drawing, used universally for a long time for communicating designer's ideas to part manufacturing on a shop floor [7].

Another media that customer can use to communicate with manufacturers is sketch. Freehand sketch is a quick rough drawing for portraying ideas, and commonly used during the conversation to elaborate an explanation. Typically, a sketch is started with single lines, also known as non-overtraced strokes. Unless these lines unambiguously represent idea, additional lines are drawn repeatedly over the existing lines. This is known as a sketch with overtraced strokes [8]. So far, geometrical reconstruction has been researched to support reconstruction of 3D CAD model from online sketch on a tablet PC [9-11] and a non-overtraced sketch on a paper [12-14] while a paper-based overtraced freehand sketch is commonly found in practice.

Therefore, there should be a system that allows 3D model to be reconstructed from a paper-based overtraced freehand sketch. Furthermore, it is foreseen that direct interfacing a paper-based overtraced freehand sketch with RP will shorten product development time.

Presented in this paper is an ongoing research on direct fabrication of a physical prototype from a paper-based overtraced freehand sketch. In the next section, the system overview is presented, and followed by the current state of the research and implementation. The conclusion and future work are addressed in the last section.

2 System Overview

Although a paper-based overtraced freehand sketch is simple and convenient, its extended applications are limited. To be workable in subsequent operations, a designer is required to translate lines and to create a 3D model manually. For constructing a prototype, the obtained CAD model is fed into a typical RP process that will first convert a 3D model to be an STL model before being sliced. This tessellated model is only an approximation that its accuracy and file size are dependent upon the number and sizes of all triangular facets [15]. Several researches have been conducted to minimize errors from STL conversion [16] and even further avoiding it with direct slicing concept [17].

In order to support a fabrication of a physical prototype from a sketch, "direct interface between a paper-based overtraced freehand sketch and RP" is being researched. This system is intended to bypass 3D model reconstruction and STL conversion to speed up process. Sliced file will be generated directly from a paper-based overtraced freehand sketch. This system composes of two key modules: single line drawing identification and contours generation. The input to the system is the image of an overtraced freehand sketch that the number of overlapping lines and their starting points and endpoints are unknown, since available information is limited to a batch of points. Therefore, the first module is being developed for transforming a paper-based overtraced freehand sketch to be a single line drawing such that additional information can be extracted. The obtained single line drawing will be sent to the second module that will be developed to generate a stack of contours. An algorithm will be developed to analyze the complexity of the appeared object on the drawing, to identify acquisition position, and to construct a contour at that position. The result of the second module is a stack of contours that will be used to generate commands directly for fabricating a physical prototype layer by layer.

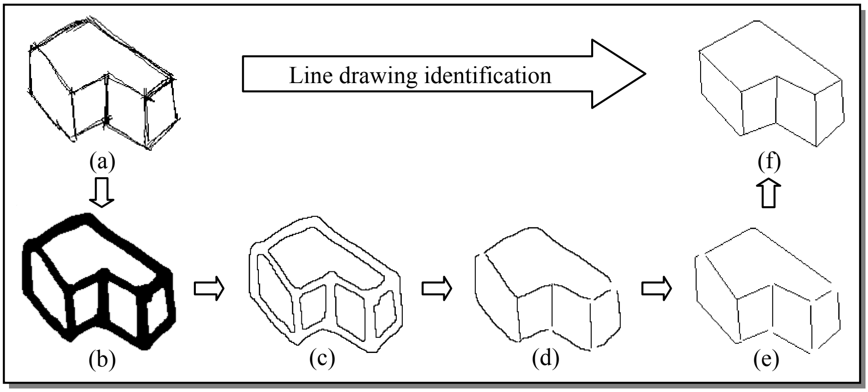

Figure 1. The current state of single line drawing identification (a) an overtraced sketch, (b) a thick line sketch, (c) a dual line sketch, (d) a segment sketch, (e) a fitted segment sketch, and (d) a single line drawing

3 The Current State of the Research

This section presents the progress of this research. Currently, this research focuses on the first module to identify a single line drawing from a paper-based overtraced freehand sketch. Our first attempt to identify a single line drawing from an overtraced freehand sketch was developed based on the assumption that the point density is higher at corners than on edges [18]. Vertices-then-edges identification approach was pursued. The developed algorithm filled overtraced lines to form thick line sketch; filtered out the low density areas; and identified vertices from the centroids of the remaining high density areas before forming edges. However, the algorithm did not guarantee that all corners would always have higher point densities than edges; and some imaginary lines created were not marked on the original image, although the representative points were found. As a result, a new approach has been introduced. As illustrated in Figure 1, this new approach tries to obtain edges first [19]. Similar to previous approach, the new algorithm first combines overtraced lines to form a thick line sketch, but instead of seeking for corners, boundary extraction is applied. That results in a dual line sketch (Figure 1c). Segments representing edges can be obtained by expanding internal contours and/or shrinking external contour simultaneously. The obtained discrete segments will then be connected to form line drawing of the sketch.

Since it was first introduced, the algorithm has been improved. The time-consuming vector scan method has been replaced by morphological dilation and erosion operations for expanding and shrinking activities. The line drawing creation part has also been updated. The steps taken in the four main activities: thick line sketch creation, contour boundary extraction, segments identification, and line drawing creation are presented in Figure 2.

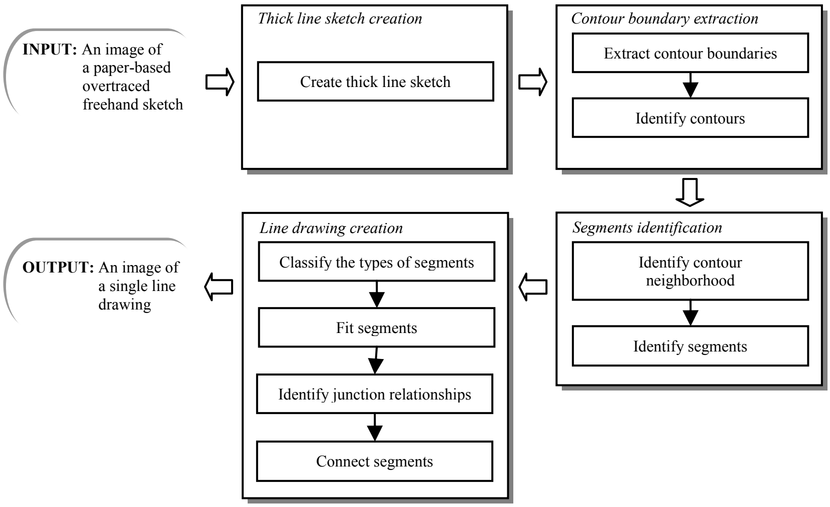

Figure 2. The overview of single line drawing identification

3.1 Thick Line Sketch Creation

A binary image of an overtraced freehand sketch, an input to the system, will be transformed to be a thick line sketch in this step. The process starts with acquiring data points in the window with size about the largest gap between overtraced lines in the sketch. This window is slid along the sketch image from left to right and top to bottom. At each position, the center point of the window is recorded on a new image, if the number of data points inside the window is greater than or equal to an assigned threshold value. By overlapping the windows, these recorded points will form a thick line sketch.

3.2 Contour Boundary Extraction

After the thick line sketch is created, the next step is to extract contour boundary and to identify contours. This process applies morphological operation to erode data points on the image. A 3×3 window is slid on the image of the thick line sketch from left to right and top to bottom. The center point of the window is drawn on the new image, if eight pixels exist in the window including the center. This operation results in a dual line sketch which always gives a set of closed contours. A contour tracing algorithm [20] is then applied to obtain ordered sequences of external contour and internal contours.

3.3 Segments Identification

This process starts from identifying contour neighborhood. The segments are determined from every two contours that are said to be neighbor. By resizing these contours toward each other, segments can be formed. Morphological dilation and erosion operations are applied to expand internal contours and shrink external contour respectively. During resizing process, points on segments in the narrowest gaps will appear first. All points will appear after points in the largest gap area meet. The wide span from the first iteration the meeting points appearing to the last iteration may result in a line segment with more than 1-pixel-wide. Therefore to achieve a 1-pixel-wide line segment, stopping condition, formulated statistic values representing the average and standard deviation of the shortest distances between points on the two contours, is applied. The obtained segment sketch is sent to the next process for creating line drawing.

3.4 Line Drawing Creation

The segments, obtained from contour expanding and shrinking technique, can be classified into three types: straight line segments, intersecting line segments and curve segments. For identifying types of segments, linearity analysis is performed first to separate segments into two types: straight line segments and non-straight line segments. A segment is a straight line, if mean square error (MSE) between the observed data and the fitted data is less than or equal to a threshold value which is 4 according to our experiments. For obtained straight line segments, linear least square fitting is applied. In case of non-straight line segments, a local maximum curvature is applied to divide each of the segments into sub-segments at dominant points where a segment changes its direction. Starting from one end of the segment, dominant point candidates are assigned for every five consecutive points. Tangent angles are calculated for all candidates. The points that the angles exceed the acceptable range will be dominant points. Linearity test is performed again on each of sub-segments. Unless it is a straight line sub-segment, Sturges's rule is executed to identify the number of control points before interpolation is applied. Sub-segments belonging to the same segment are then connected.

After beautifying all segments, their junctions are identified. A junction is defined as a single point where at least three segments are met. A matrix is created to represent relationships among all contours. To reduce the computation time, combination method is then applied to only internal relationships to generate all possible candidates for internal junctions. The internal segments are checked against the obtained junctions and those segments that still have free end will be connected to the external segments. The junction identification steps are illustrated in Figure 3.

To form a junction, the associated segments are extended (extrapolated) to intersect with each other. Ideally, they will meet at one location, and that point will be a junction. In practice, however, they often meet at different locations and form a triangle. In this case, the centroid of the triangle is used to represent the junction. A single line drawing is created after all junctions are connected.

4 Implementation

All algorithms, developed for the four steps, have been implemented on LabVIEW program and have been linked to form the first module. Illustrated in Figure 4 is the front panel screen of a single line drawing identification module. To execute this program, a user is asked to upload a binary image of an overtraced freehand sketch. This input is displayed on the top-left side of the screen. The four images in the right side of the screen show work in process. A single line drawing, an output of this program, is shown at the bottom-left corner. The program has been tested with several examples. The examples are shown in Figure 5.

5 Conclusions

This paper presents an ongoing research on adaptive layered manufacturing from overtraced freehand sketch with the objective to direct interface a paper-based overtraced freehand sketch with RP. At the present state, a single line drawing idnetification module is being developed and implemented. This module transformes an overtraced freehand sketch to be a single line drawing. For the future work, an algorithm will be developed to analyze and acquire the information of a single line drawing to generate commands for fabricating a phyiscal prototype.

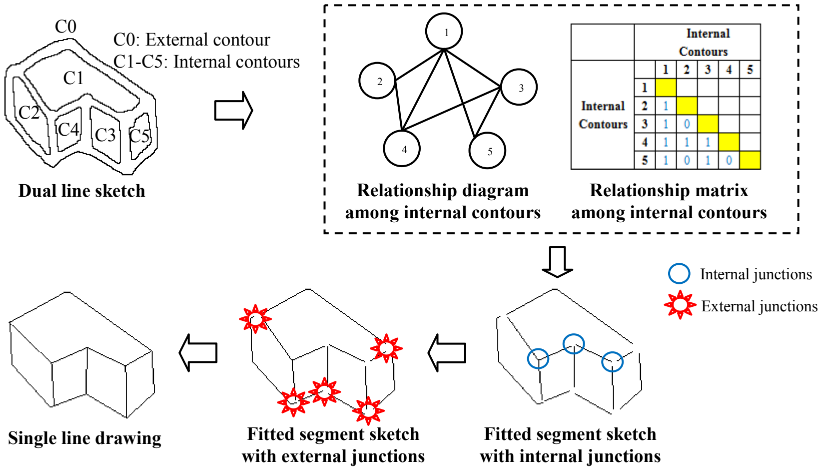

Figure 3. Junctions identification

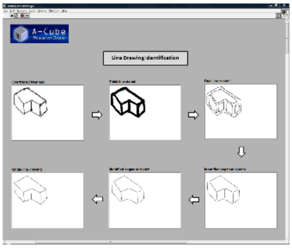

Figure 4. The front panel of single line drawing identification program

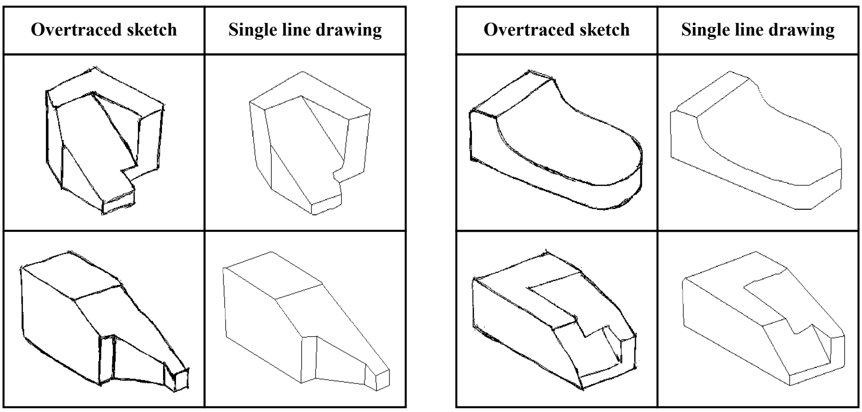

Figure 5. Examples of single line drawing identification

6 References

[1] Anderson DM. Design for manufacturing. Lafayette, California: CIM Press, 1990.
[2] Wallace TF. Customer-driven strategy: winning through operational excellence. Oliver Wight Publications, Inc., 1992.
[3] Xie SQ, Tu YL. Rapid one-of-a-kind product development. The International Journal of Advanced Manufacturing Technology 2006; 27: 421-430.
[4] Chua CK, Leong KF. Rapid prototyping: principles & applications in manufacturing. John Wiley & Sons (Asia) Pte Ltd., 1997.
[5] Lee KH, Woo H. Direct integration of reverse engineering and rapid prototyping. Computer & Industrial Engineering 2000; 38: 21-38.
[6] Liu GH, Wong YS, Zhang YF, Loh HT. Modeling cloud data for prototype manufacturing. Journal of Materials Processing Technology 2003; 38: 53-57.
[7] Soonanon P, Koomsap P. Towards direct transformation of orthographic-view drawings into a prototype. Virtual and Physical Prototyping 2009; 4(2), 75-90.
[8] Lim S, Qin SF, Prieto P, Wright D, Shackleton J. A study of sketching behavior to support free-form surface modeling from online sketching. Design Studies 2004; 25: 393-413.
[9] Shesh A, Chen B. SMARTPAPER: an interactive and user friendly sketching system. Proceedings of Eurographics 2004, 2004.
[10] Ku DC, Qin SF, Wright DK (2006) Interpretation of overtracing freehand sketching for geometric shapes. Proceedings of WSCG' 2006 Conference in Central Europe on Computer Graphics, Visualization and Computer Vision, Plzen, Czech Republic 263-270
[11] Pusch R, Samavati F, Nasri A, Wyvill B. Improving the sketch-based interface: forming curves from many small strokes. International Journal of Computer Graphics 2007: 23(9); 955-962.
[12] Marti E, Regions J, Lopez-Krahe J, Villanueva JJ. Line drawing interpretation as polyhedral objects to man-machine interaction in CAD systems. Pattern Recognition and Image Analysis 1995; 1-12.
[13] Haron H, Mohamed D, and Shamsuddin S.M. Extraction of junctions, lines and regions of irregular line drawing: the chain code processing algorithm, Jurnal Teknologi 2003; 1-28.
[14] Farrugia PJ, Borg JC, Camilleri KP, Spiteri C, Bartolo A. A cameraphone-based approach for the generation of 3D models from paper sketches. EUROGRAPHICS Workshop on Sketch-Based Interfaces and Modeling 2004; 33-42.
[15] Cao W and Miyamoto Y. Direct slicing from AutoCAD solid models for rapid prototyping. The International Journal of Advanced Manufacturing Technology 2003:21; 739-472.
[16] Luo RC, Chang YC and Tzou JH. The development of a new adaptive slicing algorithm for layered manufacturing system, IEEE, 2001; 1334-1339.
[17] Jamieson R and Hacker H. Direct slicing of CAD models for rapid prototyping. Rapid Prototyping Journal 1995:1(2); 4-12.
[18] Chansri N, Koomsap P. Identifying single line drawing from paper-based overtraced freehand sketch. Proceedings of 9th Asia Pacific Industrial Engineering and Management Systems Conference, Bali, 2008.
[19] Chansri N, Koomsap P. Line extraction for identifying single line drawing from paper-based overtraced freehand sketch. Proceedings of the 16th ISPE International Conference on Concurrent Engineering, Taipei, Taiwan, 2009; 455-463.
[20] Kuagoolkijgarn P, Koomsap P, Chansri N. A new algorithm for tracing nests of interconnected contours. The International Journal of Advanced Manufacturing Technology 2010. doi: 10.1007/s00170-010-2540-7

http://www.springer.com/978-0-85729-023-6

New World Situation: New Directions in Concurrent Engineering
Proceedings of the 17th ISPE International Conference on Concurrent Engineering
Pokojski, J.; Fukuda, S.; Salwiński, J. (Eds.)
2010, XX, 610 p., Hardcover
ISBN: 978-0-85729-023-6