Line-Art and Its Mathematical Models

Xu Yingqing (徐迎庆), Hans Dehlinger (汉斯·德灵格)\(^2\)
Qi Dongxu (齐东旭)\(^3\) and Liu Shenquan (刘慎权)\(^1\)

\(^1\) CAD Laboratory, Institute of Computing Technology
Chinese Academy of Sciences, Beijing 100080, P. R. China
\(^2\) Department of Product Design, University of Kassel, Kassel, Germany
\(^3\) CAD Center, North China University of Technology, Beijing 100041, P. R. China

Received August 15, 1996; revised January 23, 1997.

Abstract

In this paper, the authors describe the principles of Straight Line Strokes illustration, present the mathematical model of the principles, and show how a great number of lines can be implemented as main part of an automated drawing system named Line-Art. Different from traditional drawing art, Line-Art generates pictures without curves, colors, ink marks, brushes, and oil paint, but only with straight line strokes. Generated pictures are composed, clipped, and plotted. The paper also introduces how to use the initial value problem of the ordinary differential equation to describe a drawing art, e.g. Line-Art.

Keywords: Computer art, mathematical model, Line-Art, ordinary differential equations.

1 Introduction

In 1980s, Hans Dehlinger presented a special method of generating complex pictures with computers named Line-Art. Different from traditional drawing art, Line-Art generates pictures without curves, brushes, colors, ink marks, and oil paint, but only with straight line strokes. Complex pictures are generated by composing, clipping, and plotting a large number of broken-lines in which every broken-line has a special definition and connotation. Line-Arts have been exhibited in many countries on SIGGRAPH Traveling Art Show 1989. The authors of this paper have cooperated to develop the Line-Art software on Apollo Workstation and set up its mathematical models since 1990.

2 Importance and Fascination of the Line

It is well known that the line is one of the basic elements in drawing art, the strokes of a pen-equipped hand which add up to form a drawing are elementary expressions of human will to design. Drawing has existed since man first began to depict his environment. Stone age document of multiply scratched stone board may date back 30,000 years in history. The lines in the drawing have composed the beautiful shapes in the ancient art objects. Lines are very important elements in Chinese traditional painting too. The persons, the mountains and rivers, the flowers and birds, all of them have been expressed with the line as the composition language in Chinese painting. The Chinese calligraphy, in fact, is the activity of abstract lines, and they can strongly express the author's idea, emotion, and

This project is supported by the National Natural Science foundation of China.
character. In the western painting, the lines are also very important, the lines that come from the great masters' hand have very distinctive characters. We know that the lines have their special connotation in the model design as follows.

- Line is the skeleton of the forming.
- Line moves to generate the surface.
- Line is the connection of points, and the edge of the surface.
- Line produces a cushioning effect on color conflict.
- Line can be used to express the emotion by shapes (curve, straight, slanting, ...).
- Line is an abstract language in painting.
- Line can be used to express a rhythm in drawing.

3 Hand-drawing and Machine-drawing

It is interesting to compare the production processes of both the hand-drawing and the machine-drawing. People can create an unbelievable multitude of lines by hand. But obviously the abilities of the human hand are limited. More lines, more difficulty, specially for lines requiring some distinct features. If we use computer to create a large number of lines with special features it would be much easier.

Some characteristics of hand-drawing are the following:

- Usually no line equals another. Only through enormous concentration is it possible to draw identical lines.
- The position of pen to paper, the speed of drawing, pushing, rubbing etc., the pressure differences, the mechanics and the motion of hand generate wide spheres of expression, indescribable in geometrical terms.
- The hand that draws lines operates under the constant control of the eye, thereby allowing a direct feedback. The spectrum of this feedback may begin with the rational control over every single stroke and may end with a totally subdued perception of all activities.
- The hand gets tired.
- The lines drawn by hand are always with more or less faint deviation.
- The hand draws slowly.

Some characteristics of machine-drawing are the following:

- The machine is indefatigable, exact, and fast.
- The machine works with constant regularity. Thousands of lines are performed under absolutely the same conditions.
- Irregularities, if they occur, are due to mechanical shortcomings like the tearing up of or the lack of absorptive capacity of the paper, dried-up pen and so forth.
- Pressure, drawing speed, the position of pen to paper, and pushing are always the same.
- The pen's activity can be controlled by an algorithm program.

This is, of course, exactly what we expect from a machine when we work in CAD. An artist, however, may find it more interesting to use the machine's stronger ability to create and compose some nice drawings. When painting, there are some artists who resort to a kind of program, a set of temporarily adopted restrictions to carry through a visual concept. Such a program can, for example, order the hand to act as follows: "make short, powerful strokes", or "draw in small, circling movements", or "go to and fro in the direction of the developing line". A computer program is a sequence of orders, that are followed by the machine. So, it is possible to develop a computer-drawing system.