37. Free Hand Plotting
   Is It Live or Is It Digital?

W. Davis van Bakergem, Gen Obata

Urban Research and Design Center
Washington University
St. Louis, MO 63130 USA

Free hand plotting is a technique to create the illusion of hand drawn sketches by means of a CAD system. Utilizing a single pen plotter and altering the holding device, squiggly line drawings can be produced which have a hand made quality and character. In addition, a software technique using postscript can be used to create images that appear to be hand drawn. This paper describes and illustrates both the pen and software technique of creating these squiggly line drawings. It further proposes several explanations for the unusual viewer response and suggests potential applications.

Figure 1. The Draughtsman          Figure 2. Draughtsman detail          Figure 3. The Writer

Introduction

The idea of a machine producing a sketch seems like a contradiction. Making a machine behave like a human and produce human-like creations has been an elusive goal for many inventors. Golems, homunculi, androids, automatons, and robots have fascinated us for
centuries. Some early efforts in the eighteenth century included a Swiss watchmaker Jaquet-Droz who built several of the first androids which were exhibited in Paris in 1775. The Writer, the Musician and the Draughtsman were three androids which he created and have appeared at various exhibitions throughout the years (see figures 1-3). These early efforts were primarily demonstrations of capabilities of current technology and typically were displayed in a carnival sideshow-like setting. In many respects they were similar to the illusions created by magicians to thrill the members of royal courts.

More recently, with the development of digital computing, the search for artificial intelligence (arguably an oxymoron) has become a serious topic for research and has profound implications for our future. These high speed, powerful computers have stimulated a debate regarding the ability of computers to think and several have been labeled ‘thinking machines’. Once again the capacity of a machine to ‘perform’ human functions astonishes and amazes the casual observer. The mathematician and logician Alan Turing devised a test to judge whether or not ‘intelligence’ has been achieved. For example, if a person is communicating through a teletype machine with a computer and through another teletype machine with a human and cannot tell which is which, then some form of artificial intelligence has been realized.

In the realm of computer-aided-design (CAD), the production of drawings was the initial mission of early commercial CAD software and hardware. The mechanical production of working drawings for architecture and engineering applications demanded precision and accuracy, and the ‘toolkits’ of these systems were analogous to the traditional drafting tools which have been in use for hundreds of years. Plotting hardware was developed with speed, precision and reliability as primary performance criteria and the capacity of these machines to outperform a human draftsman is impressive. It is amusing to see a group of people watching a high speed plotter in action for the first time; they will stare for a long time at the pen racing along the paper — almost as if a ghost were in the machine. Competition in the pen plotter market demanded faster, more precise machines capable of drawing with very fine lines and multiple colors. Engineers of plotters succeeded to the point of vastly surpassing the capabilities of a human draftsman. The drawing quality and character takes on the appearance of having been produced by a “perfect” draftsman. In the architectural profession there is a need for other types of drawings besides precise, dimensioned ones. Architectural drawing types include renderings and sketches which are usually created by a human renderer. More recently, the renderer has been aided by the use of a computer drawing that serves as an underlay which can then be re-sketched and enhanced by hand. In a sense, digital information is being translated into hand-drawn or analog information, receiving the nuances and subtle marks that only a human hand can add. Within this context of machine perfection, a technique was developed at Washington University’s Urban Research and Design Center for making the machine produce “sketches” (see figure 4).
Technique described

This new technique was discovered with the help of an obsolete Ioline single pen plotter. The plotter is an Ioline model LP3700 that had been donated to the School by an alumnus; it is slow, noisy and requires operator attention when plotting with more than one pen width or color. One night, having used up all the pens designed for use by the plotter, a cheap drawing pen was jammed into the holder and because the pen was slightly loose, a squiggly line drawing resulted. By using a slow plotter and rigging it to draw imprecise, inaccurate, random lines, the illusion of a machine producing a hand drawn sketch was created. The detachment of the pen from the grip of the plotter introduced deliberate wobble into the pen motion. The pen wobbles, skips and randomly produces a hand-drawn effect (see figures 5-6). Three variables which affect the drawing’s character were identified: pen looseness, pen type and pen speed.

Looseness variable Some degree of wobble control was introduced by devising several types of simple holding devices to allow any pen, pencil, marker, or drawing instrument to be held at varying degrees of looseness. With the aid of three machine screws at the bottom of the holder and three near the top, the pen’s looseness may be adjusted to fine tune the wobble in the pen. Further trials in wobble control led to the addition of a metal cylinder with a diameter greater than the pen’s barrel diameter. With the cylinder holder, the looseness could be tightly controlled and well as made relatively consistent. The pen is held in place by a binder clip (see figure 7) which permits the pen to move freely within the metal cylinder. When the plotter lifts the cylinder, the pen follows. The pen’s weight is the only pressure on the paper. Several drawings illustrating a variety of pen looseness are displayed on this page.
Figure 5. Early Squiggly Line Plot  
Figure 6. Squiggly Pen Plot  
Figure 7. Pen Holder

Media variable  Since the pen’s weight is the only pressure, selecting media with free flowing inks or very soft lead is necessary to achieve sufficient drawing density for legibility. Felt tip markers, pencils, paint markers, charcoal pencils, crayons, and other implements can be used for different effects (see figure 8). Each “pen” and its variety of looseness result in slightly different drawing “styles.” The best pen discovered was a PenStix which comes in three line widths and has a tough vinyl nib capable of withstanding the repeating impacts. Since the plotter takes cut sheets of paper, a wide variety of drawing paper, tracing paper, mylar, and even watercolor paper can be used as a drawing surface. One of the most convincing “hand drawn” effects is achieved by plotting on cheap, yellow tracing paper. Since the only pressure is the weight of the pen, the yellow trace does not tear.

Speed variable The variable of speed of the pen also permits slight variation in the effects created (see figure 9). Control by pen speed is closely related to pen type and especially to the rate of ink flow. A speed of 12 inches per second seems to work for most of the media tested.
Figure 8. Charcoal Plot with hand smudge

Figure 9. Severe wobble in pen plot

The result of this trial and error approach to the media (various holding devices, marking pens, speeds and papers) was a surprisingly high level of control in affecting various drawing “styles”.
Figure 10. Mendelson's Labor Hall: laser print

Figure 11. Squiggly pen plot: mild wobble

Figure 12. Squiggly pen plot: severe wobble
Figure 13. Grove of trees: laser plotter

Figure 14. Grove of trees: squiggly pen plot

Figure 15. Palm trees: laser plot

Figure 16. Palm trees: squiggly pen plot
Figure 17. St. Louis laser plot.

Figure 18. St. Louis squiggly pen plot
Software Technique Explored

As a result of the interest generated by the squiggly line pen plots, Nathan Huebner, a director of software development at Hellmuth, Obata and Kassabaum, Inc. in St. Louis, developed a postscript version of a squiggly line plot generator. Several variables were found to be controllable which would produce the effect of a sketch. Prior to plotting the user would use the “set sketch” command to create to postscript file based on the default sketch settings or values selected for a specific effect. The postscript freehand line program modifies each line according to three essential variables which can be adjusted in the program: line thickness, line end dots and line squiggle.

Line thickness:
Additional end thickness - The line ends are thickened. This gives the illusion that the person drawing the lines is pressing the pen harder at the beginning and end of each line (or moving the pen faster and slower).
Thickness drop-off - This allows for the thickness to change abruptly or gradually across the whole line.

Line end dots:
Dot percentage - Dots appear at the end of a certain percentage of the lines drawn.
Dot diameter - The diameter of the dots at line ends can be adjusted.
Dot length - The line end dots can be divided into short lines by changing the length of the dot.
Dot gap - The gap between the end of the line and the dot can be adjusted.
**Line squiggle:**

**Average segment length** - The length of the squiggles along the line can be made longer or shorter to give the effect of more or fewer squiggles.

**Long frequency** - This is the angular change per segment measured in degrees for the sine curve of the squiggle. The long adjustments affect the entire line. This sine curve is the first of two.

**Long amplitude** - This is the distance +/- from the original line that the sine wave can vary.

**Short frequency** - This is the angular change per segment measured in degrees for the sine curve of the squiggle. The short adjustments affect the entire line. This is the second sine curve of two.

**Short amplitude** - This is the distance +/- from the original line that the sine wave can vary.

This postscript version is as effective as the wobbling pen technique in creating the illusion of hand drawn sketches. Because the objective is to “mess up” the drawing a bit, the subtle differences in the effects is not significant. In fact, a thorough testing of the postscript variables by holding some constant and varying others resulted in slightly different “styles”, but the net effect of creating the illusion of hand drawn sketches was achieved no matter which setting was used. Several examples of the postscript sketches are illustrated on the following page.

![Figure 21. Short amplitude .3](image1)

![Figure 22. Long amplitude .9](image2)

Figures 19-22 illustrate two of the "set sketch" variables which may be altered to achieve subtle differences in the plots. The differences in these drawings can be seen if examined closely, but it is apparent from the entire sequence of forty-eight drawings produced for this comparison that the subtleties are not significant. It's the fact that they are not hard line, straight edged drawings which makes them read as sketches.
**Viewer Response**

The most surprising result of this serendipitous discovery was the response of architects and students to these “hand-drawn” sketches. Astonishment and amazement that these drawings were machine made was the most common reaction and stimulated an exploration of more control of the technique. In all cases, viewers seemed more attracted to the “free hand” plots. In an effort to understand the attraction/acceptance of these drawings, a simple survey was developed which requested a reaction to a comparison of convention laser plot images and the squiggly line plots. Both the loose pen and postscript versions were included and shown adjacent to a hard edged plot of the same data. A free, open response using descriptive adjectives was requested of seventeen faculty members of the School of Architecture. Two sample survey forms with responses are shown on this page. The results were consistent in the choice of type of descriptors. Although one respondent thought it was “silly” to use a computer in such a manner - that computers produce a certain type of drawing and shouldn’t be used otherwise.

![Sample survey forms](image-url)
Listed below are the adjectives used by the survey respondents to describe the plots.

**Adjectives used to describe laser plots:**
- definite, finished, flat, cold, skeletal, clean,
- sharp, precise, neutral, stiff, distant, abstract,
- concise, authentic with respect to design,
- nice, absolute, angular, repetition, vertical,
- surface, rounded corners, good for this style

**Adjectives used to describe the squiggly plots:**
- expressive, unfinished, sketchy, romantic,
- rich, simplex, soft, free, suggestive, romantically
terrifying, disruptive, ambiguous, base, rhythmic,
tumbling, interplay, movement, messy,
- undisciplined, lacks control, organic, tender, flexible,
casual, relaxed, amusing, humane, informal, soft
- focus, quick, imprecise, freehand trace overlay, loose,
- qualitative, wiggly, dotted, hairy, loose, thinking,
- working in progress, open, developing, alterable,
textured, freehanded, emotional

There are several possible explanations for this apparent “attraction”.

*Man made vs mass produced objects* - The illusion that these images are hand drawn in part accentuates the level of astonishment because highly developed drawing skills are regarded as an enviable talent, and the time invested in a unique drawing assigns a high value to that effort. In addition, one of the characteristics of hand made objects is imperfection, or to put it in more positive terms, the human touch. For example, a ceramic pot may have marks and clues that it is man made and unique even if in some minute way. On the other hand machine made products are expected to be perfect and easily produced and therefore each one is devalued because it can be easily replaced by an identical copy. Moreover, computer plots have devalued drawings by storing the digital record of the drawing data; once described, many identical copies can be made. A complete, perfect and final drawing can be discarded with no second thought because it can be reproduced easily. Hand made objects and hand drawn sketches are usually valued because of their uniqueness. It is interesting to note here that the squiggly line pen plots produced for this paper were carefully stored and regarded as unique objects. While their data is in the records, the unique instance of the drawing is not.

*Sketches permit interpretation* - In addition to the issue of uniqueness, the incomplete quality of these drawings leads to a certain openness. Hard line drawings send the message of decisiveness and finality, while sketches encourage a more active engagement by the viewer in the interpretation of what the image is representing. A fuzzy sketch allows for filling in the gaps and reading it as representing emerging ideas. Several of the survey responses implied a reading of emerging ideas and work in progress.

*Complexity is more engaging* - The squiggly line drawings contain more complexity and therefore hold attention and interest more effectively than an image which is understood quickly. The idea of complexity could also apply to hard line drawings as well, but when the drawing is produced from the same data the squiggly line pen plots are more complex because of the addition of random movements of the pen.
Fuzzy image are closer to reality - The hard line computer plots appear much flatter than the squiggly line drawings. The evenness of the line weights of hard line drawings gives objects a cardboard cutout look while the fuzzy edges of the squiggly line drawings allows for the observer to interpret more rounded corners of objects and greater depth of field.

Potential Applications

A potential use for these free hand plots might be found in examining the distinction between presentation and design graphics. Sketches are utilized for both types but for different reasons. Presentation sketches are usually created to help visualize an unbuild scene by means of experiential views and are produced when final decisions have been made. Even if the drawing is constructed by mechanical means, it is usually traced over by hand for the final rendering and detailing. These squiggly line plots offer the opportunity to create presentation images which render the natural landscape in a more believable and convincing style. Design graphics, on the other hand, are created while the design is emerging. Sketchy drawings of designs in progress have meant sketchy ideas and an interim working mode. Hand-drawn ink on mylar and other finished drawings are typically completed when final decisions have been reached and significant changes are unlikely if not impossible. One of the drawbacks of CAD drawings for early schematic design is the impression that the design has been worked out to a greater level of detail than it has. In fact, many designers have commented that working on a CAD system demands a higher level of detailed decisions at an earlier stage of the design. Each line entered into the computer has exact coordinates associated with it. While sketches are well suited for indecisiveness, most CAD systems cannot accept a fuzzy, approximate line. Most commercial CAD systems were not developed with assisting design thinking as the primary motivation but were meant to be precise drafting tools for production. Powerful capabilities are at hand once the drawing or model has been created including parametric variations, infinite viewing angles and many output media. These squiggly line plots are one potential type of output which create the illusion of a hand drawn sketch and they can be useful in the presentation of design ideas in progress. These drawings can be useful in communicating design ideas to clients and others where the data in fact represents intermediate design decisions and not final, precise conclusions. These plots may find applications in both presentation and design graphics. This usefulness legitimizes these fakes.
Figure 24. Laser plot

Figure 25. Postscript squiggly plot
Concluding Observations

There is, of course, a fundamental contradiction in these drawings. The precise definitions of lines, polygons and other graphic elements which are stored in the computer are intentionally and randomly jumbled to affect an imprecise quality. They are a new means to an old end. One of the more surprising aspects of this development is that simply a loose pen can create such believably high quality drawings.

There is no intelligence in a loose pen and the operator still must resolve all the issues of graphic techniques in drawing just as with more conventional CAD drawings. Prior planning and thinking to produce a drawing (rather than view a model) are necessary for effective control and results. For example, to effect vignetting, or softening of the edges of a drawing, explicit alterations to the data must be made prior to sending the plot to the plotter. (Yanking the pen out in mid-plot works, but getting it back in is a feat of hand eye coordination). Certain data are more convincing as a squiggly line drawing than other data. For example, trees that look strange when plotted as hard-lined plots are believable as squiggly line drawings.

One might conclude that these free hand plots represent a reversal of the meaning of free hand sketches. When sketching by hand, emerging ideas are given some degree of manifested form in a process of visualizing the current state of the design, and, in fact, there are theories which propose direct connections between design thinking and hand motions in sketching. Here drawing firms up fuzzy thinking. The act of drawing and observing the drawn image becomes an integral part of the design process — an iterative loop between thinking, drawing.
and seeing. On the other hand, these free hand plots loosen up hard data to create the illusion of a sketch. They back away from re-presenting the data as it exists in the machine and could be used to indicate that although the data is precise, the thinking about the design is still evolving.

References

The images of androids are from-

The postscript code for the squiggly line laser plots was written by Nathan Huebner of HOK Inc in St. Louis, Missouri.