Mimicking Hand-Drawn Pencil Lines

Zainab Meraj* University of Victoria
Brian Wyvill* University of Victoria
Tobias Isenberg† University of Groningen
Amy Gooch* University of Victoria
Richard Guy‡ University of Calgary

1 Introduction

Our research capture the essence of a single stroke drawn by humans as straight pencil lines of arbitrary length, and encode it into an algorithm to generate strokes. This algorithm can produce a line that resembles a human-drawn line, and use it to replace traditional computer-drawn lines (e. g., [Bresenham 1965]). We divide our algorithm for generating a human-like drawn line into two parts: (a) synthesizing the path that corresponds to human arm movement and (b) synthesizing the pencil texture applied along the path. We are inspired by the textures produced by real pencils, similar to the work by Sousa and Buchanan [2000], by texture synthesis methods like the one by Gagalowicz and Ma [1985], and a mathematical model for arm trajectory by Flash and Hogan [1985]. Our contribution, thus, is a high quality pencil media line reproduction agent for creating aesthetically pleasing lines that mimic human-drawn lines.

2 Approach

Path: We use the Flash and Hogan method as it provides "the smoothest motion to bring the hand from an initial position to the final position in a given time" [Flash and Hogan 1985]. Our lines are defined by a fourth degree polynomial in which takes a starting and an end point and forms a realistic human trajectory between them. To represent a slight variation from the path formed by the mathematical model, we introduce a deviational parameter we call *squiggle* as an extension to the Flash and Hogan model. Experiments were conducted to validate this choice.

Texture: We simulate a range of pencils types, including *2H*, *H*, *HB*, *F*, *B*, *3B*, *6B*, and *8B*. Our algorithm correctly captures the textural properties of the pencil texture by collecting the histogram of the grey levels for the line image and then computing its co-occurrence matrix (CCM). According to our analysis of pencil behavior, we distribute the grey levels in the generated spline, replicating the measured histogram. To apply the CCM, grey values of pixels are then read in 3×3 pixel neighbourhoods along the length of the line. Each pixel is compared to its neighbours and the resulting combinations is checked against availability in the CCM, then they are either replaced with an existing combination or left unchanged. Once complete, a single-pass Gaussian filter is applied to the generated lines to reduce tone differences and filter out aliasing effects.

Results and Applications: Our human line drawing system is implemented in C++ and runs on a 2.00 GHz Intel dual core processor workstation without any hardware optimization. Table 1 provides a comparison between our synthesized lines and hand-drawn lines. We also conducted a study to test our algorithm. A paired sample t-test showed that our computer-generated lines were significantly more often thought to be hand-drawn than the other way around (paired $t(10) = 2.849, p < .05$). We have applied our work in four domains: space filling curves, architectural drawings (CAD, Google Sketch up), line patterns generated from the Life Game, and reproductions of artist's drawings (see some examples in Figure 1).

*e-mail: {zmeraj|blob|amy}@cs.uvic.ca
†e-mail: isenberg@cs.rug.nl
‡e-mail: rkg@cpsc.ucalgary.ca

Line type	Real human line	"HLA"-generated lines
H		
HB		
B		
3B		
6B		
8B		

Table 1: *Line samples: comparison of hand-drawn lines with synthesized lines (deviation parameter set to zero).*

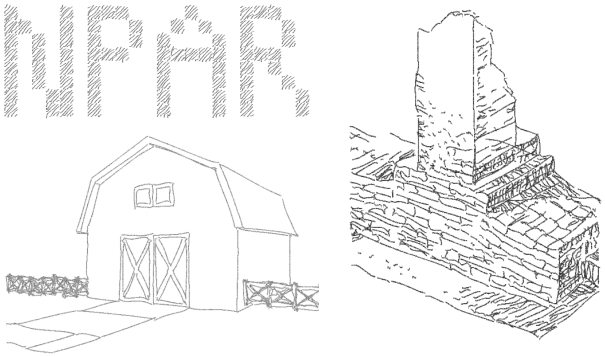

Figure 1: *Line hatching (6B pencil), a barn (H pencil), and a traced human drawing (B pencil), all rendered using our algorithm.*

3 Conclusion

We provide a system that will serve as a high quality pencil line reproduction agent, to create aesthetically pleasing pencil lines that mimic human-drawn lines by using an image synthesis method and human arm movement replication. The method avoids computationally expensive techniques and large storage space.

References

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