Procedural Animation Technology behind Microbots in Big Hero 6

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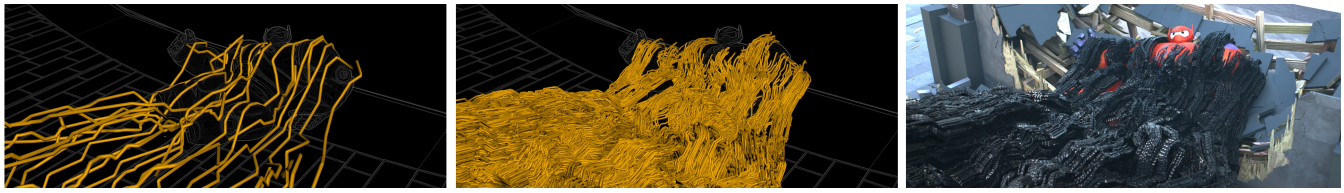

Figure 1: *Left: Base Curve. Middle: 3D Circuit Board Pattern. Right: Instancing and Rendering*

1 Introduction

In ***Big Hero 6***, tens of millions of tiny robots called Microbots connect together via electromagnetism to create dynamic animated structures. The Microbots rearrange by passing each other over bundles of themselves. In order to achieve a high level of precise control for elaborate art direction, we developed specific procedural animation algorithms.

2 Shape and Motion Design

Inspired by cooperative behavior of ants, individual Microbots perform a collaborative machine-like flipping motion to transport themselves, similarly to mechanical crowd surfing. An animated 3D circuit board pattern is a constant signature in the design of the linearly transforming bundles, supporting both the high-tech aesthetics, and self supporting structural integrity.

3 Algorithms

A procedural flipping algorithm and a procedural circuit board pattern generation algorithm were implemented to achieve the main design goals. They are categorized as two types of procedural animation.

$f(x,t)$: History Independent Proceural Animation
$f(x,t),f(x,t-1),...,f(x,0)$: History Dependent Procedural Animation

The former was used for the flipping algorithm which executes repeated passing over motion. By analyzing each Microbots' moving pattern within the passing over motion cycles, we classified them into 7 different behaviors. Using the concept of time step, we extracted specific pre-defined procedural rules for each behavior. In this analysis, a Microbot performs one of the 7 behaviors depending on which time step it is at.

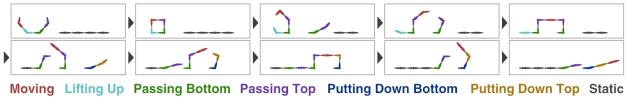

Figure 2: *Microbot Flippers Behaviors*

The circuit board pattern generation algorithm was derived from the latter. During each iteration, 45 degree angled animated branches are generated on a base curve, merged into it, and finally a new curve is extruded which would be used as a base curve in the next iteration. The curve shape of a certain iteration depends on the history of how the curves have been generated up to the previous iteration. Over the course of all iterations the curves generated by the algorithm avoid self collision and are non-intersecting.

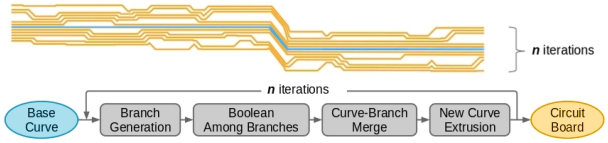

Figure 3: *Circuit Board Generation Algorithm*

4 Tools and Rigs

Attributes stored in base curves would specify how the tools generate different microbot pattern per base curve.
The Microbot Flippers tool definines position and arm directions of points along curves using the procedural flipping algorithm, and sets the correct instance attributes for each individual component of the Microbots for rendering. Per base curve, the number of Microbots, moving speed, motion timing per cycle, and motion direction are controllable.

Figure 4: *Flippers Per Base Curve Control*

The Microbot Circuit Board Generator duplicates non-colliding 45 degree branch containing curves out to a certain direction as the algorithm has been designed. Artists control number of iterations, branch scale, branch moving direction, and branch moving speed per base curve, which are stored as primitive attributes. Recursive use of multiple tools allowed multi levels of bundling. Through the use of two circuit board pattern generators, animated 3D circuit board patterns could be created.

Figure 5: *3D Circuit Board Pattern Generation*

5 Conclusions

The flipping algorithm and the circuit board pattern generation algorithm were the two most essential algorithms defining the main design characteristics of the Microbots. They facilitated the development of flexible and robust toolsets, enabling us to make an aesthetically unique effect and a technically conceivable Microbots system for the film. The procedural animation techniques were productively beneficial, and provided artists a more intuitive and interactive work flow.

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