Artist-directed Modeling of Competitively Growing Corals

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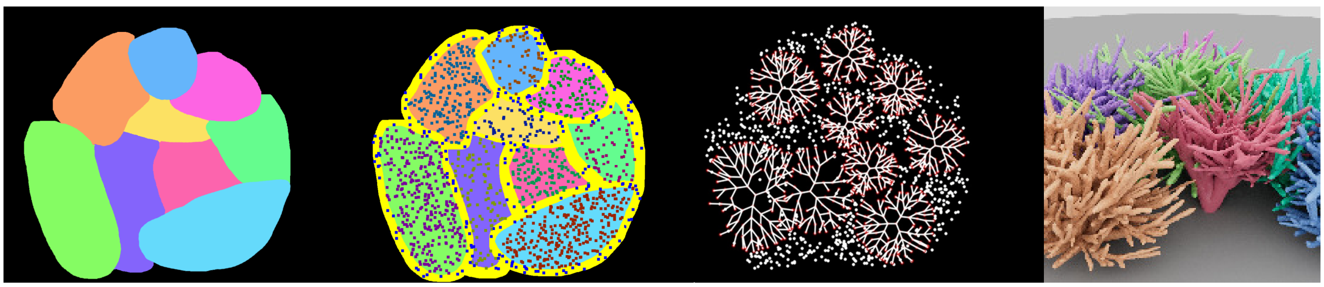

Figure 1: Overview of the proposed system. (a) The user specifies territorial areas of individual corals. (b) The system arranges locator points in each area and the margin area between neighboring corals. (c) Coral skeletons grow according to species-specific branching rules and the locator placement. (d) The resulting coral shapes.

ABSTRACT

This paper presents a procedural modeling method for coral groups considering the territorial conflict between species. We developed a graphical interface to control the territorial battle by arranging locator points that represent available space to grow the coral branches. The coral skeletals are generated according to species-specific structural rules while competing for the locators between individuals.

CCS CONCEPTS

• **Computing methodologies** → **Shape modeling**.

KEYWORDS

procedural modeling, coral, competitive growth

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1 INTRODUCTION

Coral reefs are critical for visual expression of warm underwater scenes. A simple approach to creating the reef scene is arranging various coral models, such as reef-building and gem corals. Since the corals have fractal-plant-like branching structures, the rule-based modeling techniques have been applied to generate a wide variety of coral shapes with a few manual parameters [Prusinkiewicz and Lindenmayer 1996; Runions et al. 2007].

In addition to the internal structural rules of individual corals, the coral reef ecosystem should be considered to generate a convincing scene. The coral is a territorial animal; each coral tries to receive more sunlight by spreading the branches while attacking neighboring individuals using tentacles. The territorial behavior determines complex boundary shapes between the neighbors. Furthermore, manual layout control is also crucial to reflect the designers' intention for the scene. Territory areas should be arbitrarily designed even if the user inputs violate some natural rules.

Our research aims to develop an artist-friendly system to generate coral reefs considering the species-specific shape features of individual corals and the coral reef ecosystem. Our algorithm represents an available space for growth by a set of locator points. Our system provides a graphical interface to control locator placements for indirectly designing the coral shapes. First, the user roughly specifies the territory areas of each coral. Next, locator points are arranged in each territory area. Finally, the skeletal structure of each coral grows based on the species-specific structural rule while competing for the locators. Our intuitive interface enables the efficient design of naturally entangled corals with less special knowledge.

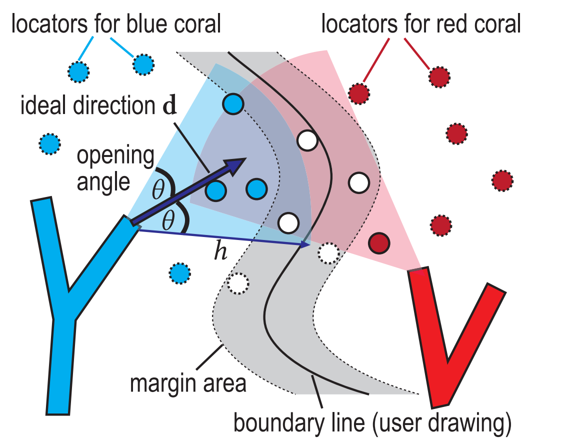

Figure 2: Two corals grow their branches. The end-tip of each branch searches locator points assigned to the individual and competes for free locators in the margin area. The ideal growing direction is determined according to the formal shape grammars of the L-system.

2 PROPOSED METHOD

Our method uses a self-organizing tree model [Palubicki et al. 2009] to generate a coral skeleton. This method combines the L-system [Prusinkiewicz and Lindenmayer 1996], and the space colonization method [Runions et al. 2007] that represents available spaces for growing a new skeletal branch by a set of locator points. Our key idea is to arrange the locator points using an intuitive interface that is not addressed in previous studies. The coral skeletal structure is generated based on the formal shape grammar of each species and the manually-designed spatial distribution of the locators.

2.1 Arrangement of Locator Points

Users can control the coral structure by editing the shape grammar and arranging the locator placement. The user first draws the closed boundary curve of each coral territory on a ground surface and specifies the maximum height of the locator from the ground. The specified number of locator points are arranged in the bounding volume and assigned to the corresponding coral, as illustrated by the blue and pink circles in Figure 2. Our current implementation randomly sets the maximum height of each coral and determines the locator positions by randomized sampling. More precise manual control is possible by improving the graphical interface.

To emulate the territorial conflict, the locator around the bounding surface is associated with any corals, as illustrated by the white circles and gray region in Figure 2. Therefore, the actual outline of synthesized coral is determined due to the territorial conflict in the margin area, where the user-specified boundary is used as a loose guideline.

The locator placement also determines the branch length of the individuals. For instance, dense locator distribution corresponds to a coral having dense and short branches, and the sparsely distributed locators should provide a few long branches. The branch length is calculated in proportion to the average distance between any two locators in each territory.

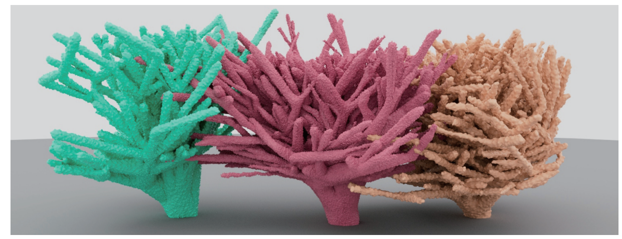

Figure 3: Coral shapes generated using different locator densities and shape grammars. Neighboring corals have entangled branches due to the territorial conflict.

2.2 Branch Growth Rules

Each coral starts growing from the center of the territory. Ideal child direction $\mathbf{d}$ from a parent branch is determined according to the internal structural rule represented by a formal grammar of the L-system. Let the terminal position of the parent branch be $\mathbf{b}$ and a set of P locators be $\{\mathbf{p}_i, | i \in \{1, \cdots, P\}\}$. The locators are searched in a cone-shaped area whose principal axis is the ideal growing direction $\mathbf{d}$, and the distance and the opening angle are h and θ, as illustrated in Figure 2. Our system searches for locators higher than the parent node $\mathbf{b}$ to extend the child branch upward. The actual growing direction of the child branch is towards the centroid of the found locators that is expressed by $\left(\sum_{i\in\mathcal{I}} \mathbf{p}_i\right)/|\mathcal{I}| - \mathbf{b}$ where $\mathcal{I} \in \{j \mid \|\mathbf{p}_j - \mathbf{b}\| \le h \wedge (\mathbf{p}_j - \mathbf{b})\cdot\mathbf{d} \ge \|\mathbf{p}_j - \mathbf{b}\| \cos\theta\}$.

The growing process is synchronized among all individuals; the first branches simultaneously grow from the root for all individuals, and the second-generation branches are generated in the next step. If different branches simultaneously find a locator, it is assigned to the nearest branch, mimicking the first-come-first-served territorial behavior between neighbors.

3 RESULTS

Figure 3 shows coral shapes generated by our method, where the surface mesh and displacement maps were created using a standard graphics tool. Each individual was generated with a different shape grammar. Entangled branches were naturally produced without penetrations by mimicking the territorial conflict. Please refer to the supplemental video for more examples and a comparison with an actual photograph. A limitation of our method is that layered structures cannot be produced using the 2D interface to specify the territory region. Our future work includes the development of an intuitive interface to specify a volumetric locator distribution considering the coral ecosystem.

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