

POSTER

SYNTHESISING STALACTITE MORPHOLOGY

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A topic of major interest in speleology is the morphology of speleothems. However, the chemical and physical processes that occur to form speleothems in nature are quite complex. Speleothem growth can be modeled computationally with the input of various parameters. One could easily explore the vast variety of potential shapes that may arise from different conditions in a cave.

Our research aims toward the goal of computationally modeling the morphology of speleothems. We have investigated two models for generating stalactite geometries, and rendered these geometries as realistic images.

The first of these is a rigorous model based on the thermodynamic and kinetic theory of calcite deposition. It first generates the shape of a calcite straw, based on a linear approximation of the rate of deposition. It then blocks the straw and builds up the sides and tip of the stalactite.

The second model is a stochastic particle-based approach from computer graphics. This model starts off with a cylinder, representing the straw speleothem, which is made up of calcite particles joined together by edges in the geometry. Water particles are generated at the top of the straw and allowed to flow along edges between calcite particles. Deposition occurs on every calcite particle visited by a water particle, according to the length of time the water particle is present there.

The water particles accelerate down the sides of the stalactite until they reach the tip, where they are removed, causing new water particles to be created back at the top of the stalactite.



Computational methods for synthesizing images of stalactites

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Introduction

There are two approaches to modeling speleothems: the first is based on the thermodynamic & kinetic theory of calcite deposition. The second uses computer graphics in a stochastic particle-based way. Our research focuses on combining these approaches to produce an adequate general computational model for speleothems (plate 1). At present, we are modeling stalactites to render them as realistic images.



Chemical Model

Dreybrodt (1999) and Kaufmann (2000), have produced geochemical models for stalagmites. Our model uses the same carbonate geochemistry for stalactites. The stalactite is generated in two stages: first as a straw, followed by growth of its walls and tip. Straw growth starts with a drop on the cave ceiling with calcite deposition occurring around its circumference. The rate of growth of the straw is used to obtain the straw length over a fixed number of years. When the straw is blocked, the simulation of stalactite growth starts from the top of the straw and continues down its sides. To do this the stalactite profile is broken into a number of segments. The time for a given volume of water to flow over each segment is calculated together with magnitude of calcite deposition that occurs normal to the stalactite surface. The calcite deposited solution accumulates as a drop at the tip. The water film thickness is calculated for a series of points around the tip, and a rate constant is also calculated for each point. The drop at the tip is allowed to build up until it reaches a critical volume (Or and Ghezzehei, 2000) and falls. This simulation continues for a user defined number of years, after which the 2-D profile can be displayed. The 3-D stalactite is produced from this profile in the manner of a tube. Plate 2 shows how the modeled stalactite evolves over time.

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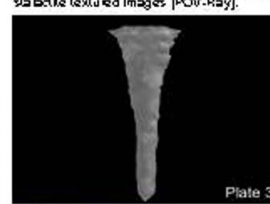


Computer Graphics Model

Baba and Coorg [manuscript] have developed a graphic model that is based on the concepts of water flow and calcite deposition. It does not attempt to accurately model the rate of growth of the stalactite. Instead, it concentrates on producing a realistic looking picture. It simulates a 3-D particle system made up of calcite particles, representing the stalactite itself, and water particles, which deposit calcite. The calcite particles are joined by edges, thus defining the overall solid geometry of the stalactite. The initial straw for our model can be obtained either by a chemical approach, or defined arbitrarily. The stalactite simulation starts by introducing water particles onto randomly determined calcite particles at the top of the straw. These water particles flow from one calcite particle to the next, starting at a given speed and accelerating down the stalactite. From any calcite particle, the target particle to which the water flows is determined probabilistically. The path of the water is defined by gravity. At the bottom of the stalactite the water particle is removed from the simulation. Then it is recreated at the top on a randomly selected calcite particle. Deposition normal to the stalactite surface occurs on any calcite particle which is visited by a water particle, perturbed slightly according to a given randomness parameter. The amount of deposition is based on a constant user defined deposition rate, taking into account the time each water particle is present at a particular calcite particle. The deposition is modeled by moving the calcite particle in the calculated direction by a given amount. In order to reduce sharp protrusions arising from the discrete depositions, a Gaussian function based on the distance of each neighbour from the main calcite particle is used to determine the amount of deposition. Next, adaptive refinement of the geometry is performed. When an edge becomes longer than a given length, it is split into two edges joined by a calcite particle. Plate 3 shows a stalactite produced by our computer graphics model.

Texturing and Rendering

Realistic images of stalactites are obtained by giving them colour and texture (Plate 4). A colour is selected from photographs, then bump-mapping is used to produce imperfections on the stalactite surface. Then the ray tracer POV-Ray is used for the final stalactite textured images (POV-Ray).



Future Directions

The chemical model gives the growth rate of a stalactite under specific given environmental conditions. Random aspects of the computer graphics model produce a realistic image with surface imperfections. It is proposed to produce a hybrid model by combining the two models. For the hybrid, a more sophisticated, generalised, water flow model will be used. Texturing was only briefly explored in this work and requires further research. It is proposed to visit the speleothems to give them a waxy appearance and their colouring will be used to trace materials present in the calcite.



References

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Stalactites generated by both models were rendered as images with realistic texturing and lighting in a ray-tracer. Although the first model provided a more chemically accurate approach to generating

geometry for a stalactite, the images produced by the second model appeared much more realistic. We aim towards a hybrid of these two approaches that may result in more realistic images.