The Algorithmic Fungus

by

David Moore and Audrius Meškauskas

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This book describes our package of interactive computer models that simulate the way filamentous fungal hyphae grow in three-dimensional space. We call it the **Neighbour-Sensing mathematical model of hyphal growth**. This three-dimensional mathematical model of hyphal growth was developed to study the morphogenesis of fungal networks. The apps that make up the modelling program allow the user to change the intimate characteristics of the growing cyberfungus. Aspects like the amount of branching, angle of branching and whether cyberhyphal threads stay together or grow apart (among several other features) can all be changed to establish their effect on the way the **simulated cyberhyphae** grow. So, the programs provide the user with a way to ***experiment*** with **virtual fungi** 'growing' in his/her computing device. It is the ultimate, most controllable, and most life-like cyberfungus you can have on your own computer; it is an experimental tool, not a game or a painting program. It provides the scientist in YOU with a way of experimenting with features that may regulate hyphal growth patterns to arrive at suggestions that could be tested with live fungi.

The book starts with a concise description of the numerous ways in which the cellular life style of Kingdom Fungi differs from those other eukaryotic Kingdoms: Plants and Animals. A particularly crucial difference that emerges is that cross-walls in living filamentous hyphae are formed ***only at right angles to the long axis of the hypha***. But most crucial of all is that a daughter hyphal apex can only arise if a branch is initiated. So, for the fungi, hyphal ***branch formation*** is the equivalent of ***cell division*** in animals, plants and protists. Fungal cells do not divide; they branch. The position of origin of a branch, and its direction and rate of growth are the main formative events in the development of fungal tissues and organs. Consequently, by simulating the mathematics of the control of hyphal growth and branching the Neighbour-Sensing model provides the user with a way of experimenting with features that may regulate hyphal growth patterning during morphogenesis.

The modelling process starts from the proposition that the cyberhyphal apex is a vector moving in 3-dimensional space which is constantly informed of its surroundings by scalar and vector fields produced in the cyberfungal mycelium; the fields and their gradients being used to inform the algorithm that calculates the likelihood of branching, the angle of branching and the growth direction of ***each*** cyberhyphal tip in the simulated cybermycelium. So, effectively, the virtual hyphal tip is sensing the neighbouring cybermycelium (this is why we call it the **Neighbour-Sensing** model).

The Neighbour-Sensing model explains how various cyberfungal structures may arise because of the 'crowd behaviour' of the community of cyberhyphal tips that make up the cybermycelium. And it does this by ***demonstrating*** that behaviour on ***your*** computer monitor. A key idea of this model is that all parts of the cyberfungal mycelium have identical field generation systems, field sensing mechanisms and growth direction altering algorithms. With properly chosen model

parameters it is possible to observe the transformation of the initial unordered cybermycelium structure into various forms, some of them being very like natural fungal fruit bodies and other complex structures. We show you how you can make the programs generate structures that mimic all sorts of fungal fruiting structures: conidiophores, sclerotia, the open more-or-less saucer-shaped or cup-like apothecia of discomycete Ascomycota, closed cleistothecial ascoma or hypogeous fruit bodies of the truffles and their allies, the perithecial flask-shaped or bottle-like ascomata of pyrenomycete Ascomycota, as well as different sorts of mushroom-like fruit bodies characteristic of the Basidiomycota, as well as brackets and shelf fungi, strands, cords and rhizomorphs. The whole Kingdom is open to your experimentation!

In these pages, we will present a complete outline of the science and mathematics that underpin the Neighbour-Sensing model of cyberhyphal growth and show a wide range of experiments done with the model. More than this, we show ***you*** how to download the freeware programs to your own computer, and provide all the documentation you will need to experience the program and carry out experiments for yourself.

Freeware downloads

All the working programs described here can be downloaded from our websites. Get the downloads (free) by going directly to the downloads page at: http://www.davidmoore.org.uk/CyberWEB/Downloads-page.htm, or to our mirror site at http://reverse-complement.com/f3d/CyberWEB/, and check out our Wikipedia page at https://en.wikipedia.org/wiki/Neighbour-sensing_model.

Section 3 of this document, starting on page 121 and entitled ***Program accessibility: experiencing the programs yourself***, includes full download, installation and operating instructions; notably a full Neighbour-Sensing User Manual. And, if you want to do a little programming yourself, the ***program listings*** are given in **Section 4**, starting on page 164.