Available online at www.sciencedirect.com
ScienceDirect
Mathematics and Computers in Simulation 81 (2011) 1553–1571
MATHEMATICS AND COMPUTERS IN SIMULATION
www.elsevier.com/locate/matcom

Original article

Modelling water droplet movement on a leaf surface

Moa'ath N. Oqielat, Ian W. Turner, John A. Belward *, Scott W. McCue

Mathematical Sciences, Queensland University of Technology, GPO Box 2434, Brisbane, Queensland 4001, Australia

Received 6 February 2009; received in revised form 22 April 2010; accepted 3 September 2010

Abstract

Modelling droplet movement on leaf surfaces is an important component in understanding how water, pesticide or nutrient is absorbed through the leaf surface. A simple mathematical model is proposed in this paper for generating a realistic, or natural looking trajectory of a water droplet traversing a virtual leaf surface. The virtual surface is comprised of a triangular mesh structure over which a hybrid Clough–Tocher seamed element interpolant is constructed from real-life scattered data captured by a laser scanner. The motion of the droplet is assumed to be affected by gravitational, frictional and surface resistance forces and the innovation of our approach is the use of thin-film theory to develop a stopping criterion for the droplet as it moves on the surface. The droplet model is verified and calibrated using experimental measurement; the results are promising and appear to capture reality quite well.

Keywords: Mathematical modelling; Surface fitting; Thin-film approximation; Clough–Tocher method; Radial basis function method

1. Introduction

An important research component of agrichemical spray retention by plants is to model and simulate droplet movement on the surface of a leaf. To this end, we present a simple mathematical model for this process, report on experimental results generated with a particular type of leaf (Frangipani leaf), and compare the results from each of the two studies. A crucial aspect of our approach is to construct the surface of the leaf using a recently developed surface fitting method [30,31] based on a combination of the Clough–Tocher method with radial basis functions.

When a single water droplet impacts on a solid surface, it may bounce off or perhaps spread out along that surface, depending on the nature and inclination of the surface, the speed and size of the drop, and the properties of the liquid, including the viscosity and surface tension. However, in reality there are more options for the fate of the droplet, and indeed Rioboo et al. [35] report that their experiments suggest the outcomes include deposition, prompt splash, corona splash, receding break-up, partial rebound, and complete rebound. These are also described qualitatively in the review article by Yarin [40]. Further, spreading drops may be characterized by instabilities leading to viscous fingering, as studied by Kim et al. [19] and Thoroddsen and Sakakibara [38], for example. An important point is that the detailed fluid mechanics of each of these outcomes is quite sophisticated, and requires high level mathematical modelling, including asymptotic and stability analysis and careful computational simulations, as well as an expensive experimental setup.

* Corresponding author. Tel.: +61 7 3138 3129
E-mail addresses: muad81@yahoo.com (M.N. Oqielat), i.turner@qut.edu.au (I.W. Turner), j.belward@qut.edu.au (J.A. Belward), scott.mccue@qut.edu.au (S.W. McCue).

0378-4754/$36.00
doi:10.1016/j.matcom.2010.09.003