Translating the Three-Dimensional Mathematical Modelling of Plant Growth to Additive Manufacturing

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Abstract. Much like how plants grow via the expansion and multiplication of cells, a 3D printed component is formed via the bonding of material point-by-point from the bottom-up. Exploiting this analogy, this work employs mathematical models of three-dimensional plant growth to further understand and aid implementation of additive manufacturing (AM) technologies (otherwise known as 3D printing). The resolution of these printed structures is of the upmost importance in the fabrication of tissue scaffolds or constructs that mimic the mechanical properties of tissues. As such, the overarching aim is to derive a generalised mathematical model to simulate the extrusion-based bioprinting process via manipulation of the underlying physics of the system. Such a model has the potential to theoretically identify which combinations of printing process parameters generate a successful resolution: the 'window of printability' of a bioink. A hydrogel typically presents a shear-thinning behaviour. In this paper we consider the simplest case: a Newtonian fluid flow far from any edge effects. An initial steady-state model for a viscous thread under extrusion using an arc-length-based coordinate system is presented. As such, this research presents a significant milestone toward representing the non-Newtonian system. This uniquely transdisciplinary methodology seeks to optimise the comparability and transferability of results across materials and laboratories and, above all, increase the efficiency of extrusion-based bioprinting and enhance design creativity by devising a user-friendly, sustainable tool for engineers to visualise AM as a process of growth.

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