Simulating plant biomechanics: gaining insights on how plants build efficient and effective morphologies

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Abstract

As a result of turgor pressure, plant cell walls have to resist large amounts of tensile stress and, if not managed properly, can lead to damage or an ineffective use of resources. As plant cells are rigidly connected to each other, to resist this mechanical stress, there has to be tight regulation of where to place a new cell wall in order to develop effective and efficient tissues. Mechanical stress created from cell and tissue scale effects in plants has also been shown to influence microtubule organisation, where these cytoskeleton components help decide the division plane, which can alter tissue stress, all part of a geometrical feedback loop. To understand how plants manage this stress, we use experimental and computational methods, such as mechanical perturbations on live tissues using an extensometer and performing finite element inflation simulations. For this purpose, we have built up and improved existing modelling software to efficiently simulate plant tissue inflation and growth in 3D and with multiple layers. Through such methods, we can investigate the consequences of cell shapes and tissue structure across multiple scales. Accompanying this software, we have also built easy-to-use meshing code to build meshes of complex 3D multilayer cellular tissues and meshes that can be created from actual data. Specifically, we can begin to understand why plant tissues divide, why they might favour 3-way junctions and why they take certain shapes. We can also examine the consequences of differential growth rates in different tissue layers on cell division. Simply put, we are asking what are the mechanical effects of cell division and where to place a new cell wall.

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