Cost-effective, high-throughput 3D reconstruction method for fruit phenotyping

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The reconstruction of fruit shape, and particularly, that of strawberry, is needed for a variety of purposes such as the assessing of market class and informing cultivar release documentation. In this work, we focus on the use of fruit shape for phenotyping and selection in breeding programs [6].

We describe a portable, low-cost turntable system for fruit shape estimation in which the fruit rotates on a spindle, as shown in Figure 1. The spindle's rotation speed is controlled by an Arduino board. The design allows the user to alter the number of cameras used for capture, so one or more cameras capture images as the fruit rotates. A complete rotation takes 9 seconds per sample, capturing $56-60$ frames per camera, per rotation. The total cost for a prototype was $\$1,600$.

Currently, we use one camera and remove the constraint that the angle of rotation be perfectly known [2, 8] by calibrating for the external camera calibration parameters for each sample. Two cubes offset from each other by 45 degrees were three-dimensionally printed and attached to the spindle. On top of each visible cube face, charuco tags, [1, 3] or aruco tags embedded in a chessboard patterns, were added. External camera calibration parameters for each image acquisition timepoint were computed using the method of Tabb and Medeiros 2019 [10].

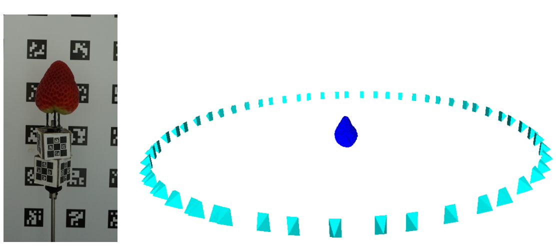

Figure 1. Left: Strawberry fruit mounted on top of spindle with charuco patterns. Right: Cyan pyramids illustrate the estimated camera positions relative to strawberry; blue region represents reconstructed strawberry.

Once the camera calibration parameters are computed, background removal is performed and a shape from inconsistent silhouette method [9] is used for shape estimation. We show the reconstructed camera positions and fruit shape of a strawberry in Figure 1.

While initially designed for strawberry, the system is also generalizable to other fruits and will also be demonstrated on at least potato in our poster. Shape from silhouette methods are able to capture convex and saddle regions, but not concavities, so will be limited to situations where concavities are not plentiful. This system computes calibration information while the samples for reconstruction are acquired, in contrast to multi-view stereo systems for plant phenotyping [4, 5, 7].

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