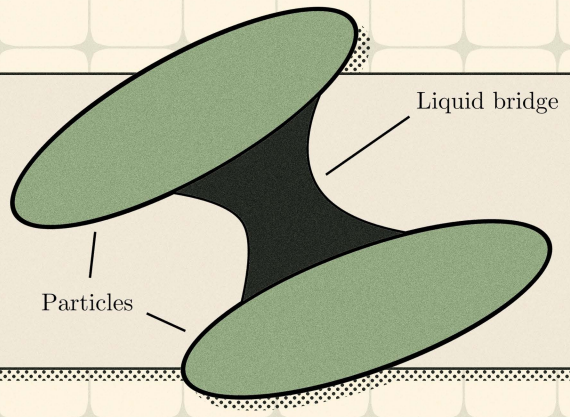
Characterising Liquid Bridges
for use in 3D-printed nutraceuticals

Liquid bridges are a naturally occurring structure in fluids between two surfaces, whose shape arises from minimising surface energy (Honschoten, et al., 2010). We are most interested in their presence in 3D-printed pastes, in which liquid bridges form between suspended particles.



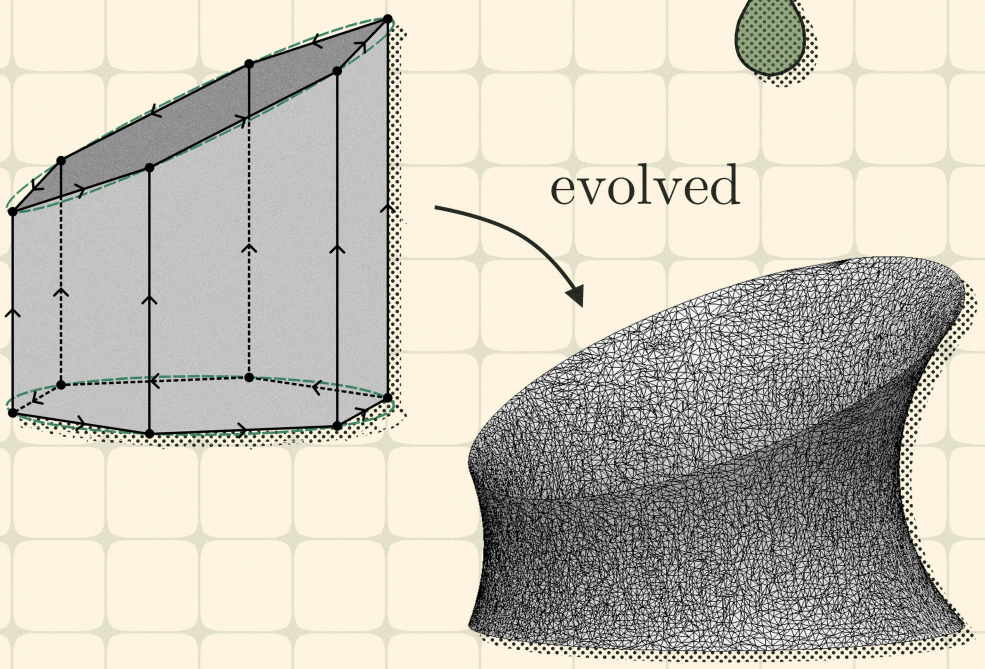
The study of liquid bridges dates back to the early work of Young and Laplace and is honoured in the naming of the Young-Laplace equation, the governing equation of the capillary pressure difference overfluid interfaces (Young, 1805; Laplace, 1806).

$$\Delta p = -2\gamma H$$

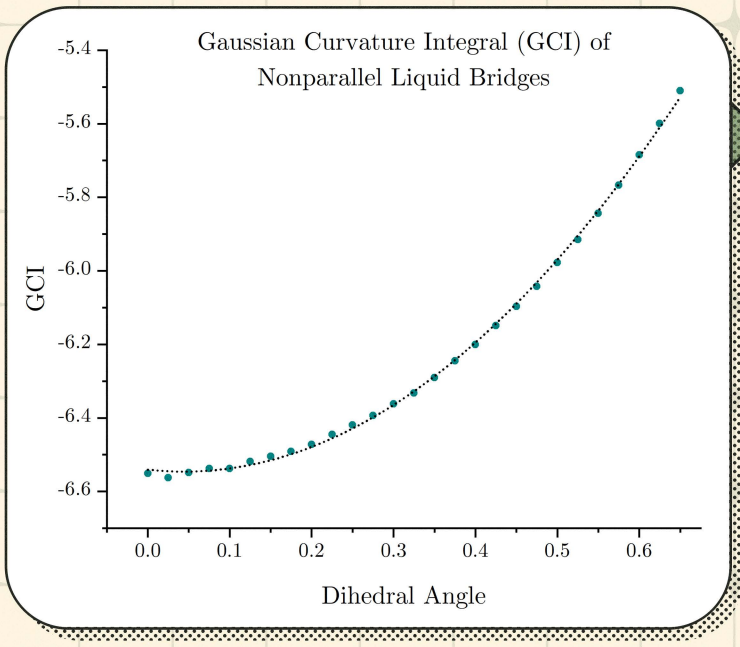
Δp: Laplace pressure; γ: surface tension; H: mean curvature

Recent research has focused on liquid bridges between non-parallel surfaces, leading to developments in 3D-printing's applications in custom medicine delivery systems (Ataei, et al., 2017; Butler & Vella, 2022).

The Surface Evolver program – used in this project – minimizes the energy of bodies via a gradient descent method, utilizing mathematical machinery to evolve models (Brakke, 1992). Surface Evolver is able to efficiently calculate various properties of the evolved bodies, such as surface tension and curvature, the data from which is collected and analysed in this project (Brakke, 2013).



Using Surface Evolver, we were able to construct a model liquid bridge between surfaces at an arbitrary angle (measured in radians) to one another. Using Surface Evolver, we were then able to calculate the Gaussian curvature of these liquid bridge shapes and see how it varies as the angle between the surfaces changes.



We found that the Gaussian curvature appears to follow a quadratic curve, specifically,

$$K \approx 2.777\alpha^2 - 0.2465\alpha - 6.5406.$$

This research is the first step towards improving structural integrity in 3D-printed pastes for custom nutraceuticals.

Ataei, M., Chena, H., Tang, T. & Amirfazli, A., 2017. Stability of a Liquid Bridge between Nonparallel Hydrophilic Surfaces. Journal of Colloid and Interface Science, Volume 492, pp. 207-217. Brakke, K. A., 1992. The Surface Evolver. Experimental Mathematics, 1(2), pp. 141-165. Brakke, K. A., 2013. The Surface Evolver Documentation. [Online] Available at: https://kenbrakke.com/evolver/html/evolver.htm [Accessed 2024]. Butler, M. D. & Vella, D., 2022. Liquid bridge splitting enhances normal capillary adhesion and resistance to shear on rough surfaces. Journal of Colloid and Interface Science, Volume 607, pp. 514-529. Honschoten, J. W. v., Tas, N. R. & Elwenspoek, M., 2010. The profile of a capillary liquid bridge between solid surfaces. American Journal of Physics, 78(3), pp. 277-286. Laplace, P.-S., 1806. Mechanique Celeste, Supplement to Book 10. s.l.:s.n. Young, T., 1805. An Essay on the Cohesion of Fluids. Philosophical Transactions of the Royal Society of London, 95(95), pp. 65-87.

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