Predicting the complex propagation of 3D fractures

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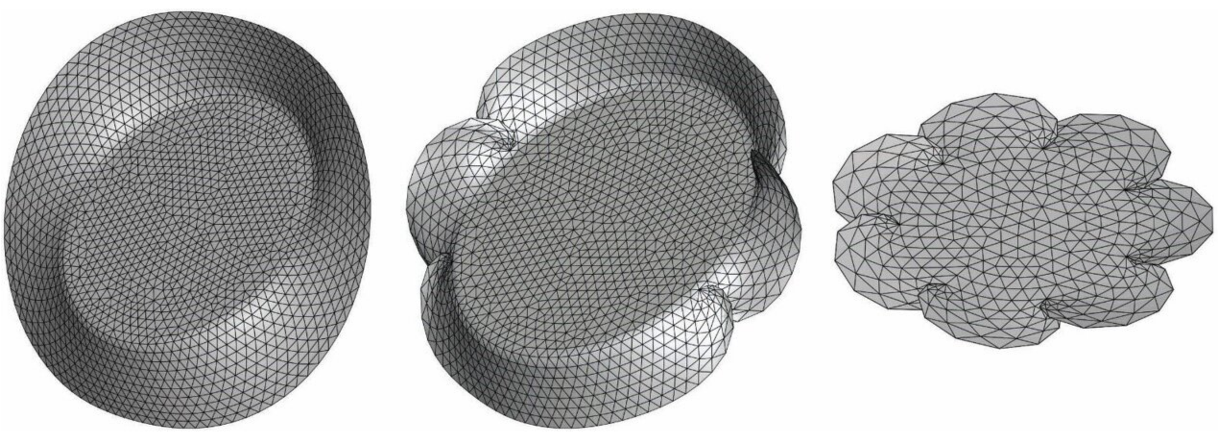

Different fracture shapes captured by the new algorithm. Credit: Louis Ngai Yuen Wong, Xin Cui

Fracture propagation is ubiquitous across different temporal and spatial scales. Examples include the breaking of a vase, fatigue cracks in machine parts, and scars left by strong earthquakes. Understanding 3D fracture propagation is challenging due to its rapid occurrence and complex fracture shapes.

In a study published in the journal *Rock Mechanics Bulletin*, a duo of researchers from the University of Hong Kong and Massachusetts Institute of Technology (MIT) have developed an advanced algorithm to simulate 3D fracture propagation under complex loading conditions, paving the way for better understanding and control of fracture propagation.

"The crux of understanding 3D fracture propagation is to unravel how fracture geometry responds to the far-field loading," explained Xin Cui, a postdoctoral associate at MIT and co-author of the study. "By leveraging fracture mechanics knowledge, we are able to convert far-field loading to near-fracture-front stresses, which play a leading role in determining the fracture shape. However, the twisted 3D geometry of fractures poses great challenges for numerical simulators."

To tackle this problem, the researchers applied fracture mechanics to their open-source code $DDFS^{3D}$. Cui explains that "$DDFS^{3D}$ excels at capturing complex 3D geometry with triangular elements and accurately calculating the stress field near the fracture front. This enables us to precisely locate the position of every bit of new fracture surfaces and reconstruct the entire fracture shape after propagation."

According to lead author Louis Wong, a Professor of Engineering Geology at the University of Hong Kong, this is a breakthrough in the rock mechanics field. "Fracture significantly influences the strength of brittle materials. The significance of this study lies not only in understanding how fracture geometry responds to loading but also in providing insights on how to control the fracture development," he said.

"In many engineering applications, such as hydraulic fracturing, the orientation of fractures has to be carefully designed to enhance productivity and reduce potential risks. The technology developed in this study facilitates achieving such goals."

More information: Louis Ngai Yuen Wong et al, Simulation of 3D fracture propagation under I-II-III mixed-mode loading, *Rock Mechanics Bulletin* (2023). DOI: 10.1016/j.rockmb.2023.100082

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