Incorporating fault kinematics into implicit modelling

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Three-dimensional geological modelling is becoming increasingly important for resource management and exploration. This usually involves collating drill hole datasets, interpretive cross sections and level maps. Structural geology observations of folds and faults are usually poorly integrated with important information such as fault kinematics, fold axes, fold axial surfaces and vergence being difficult to directly incorporate into the surface descriptions. Recent developments for implicit modelling allow for direct incorporation of fold geometries by fitting periodic profiles to structural observations. This uses a curvilinear coordinate system that represents the finite strain ellipsoid of the fold (axial foliation and fold axis direction). Faults are more challenging to incorporate because they introduce discontinuities in the surfaces being modelled that are difficult to include in the surface description. There are two main approaches that are used for incorporating the fault displacement into surface descriptions: the first approach adds a displacement function (step function) into the mathematical description of the surface. Step functions do not capture fault kinematics and are only correct for faults where the fault is orthogonal to the layers being faulted. The second approach deforms an existing continuous surface using a kinematic operator to account for the fault displacement around a curvilinear coordinate system that is based on the fault surface, fault slip direction and fault extent. This approach is capable of using fault kinematics but requires the geometry of the surface prior to faulting to be known. Neither approach is capable of modelling the interaction between faults within complicated fault networks e.g duplex systems, flower structures and listric fault systems or modelling surfaces with complex pre-fault geometries such as fold series or intrusions where the wavelength of the fold or the volume of the intrusion, provide markers for testing the fault kinematics. In this study we propose an adaptation of the kinematic fault operator. Instead of applying the operator to an already interpolated surface, the fault operator is applied in reverse to the model area and geological observations. The model area is restored to pre-fault locations and the older geological surfaces can be interpolated within this space. The kinematic operator is added to the geological surface description allowing for the faulted surface to evaluated throughout the whole model area. We demonstrate these new developments to fault modelling using the new open source probabilistic 3D geological modelling package Loop3D on two synthetic examples: a faulted intrusion and a faulted fold series.

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