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2b. The 3−D flexural unfolding technique

In addition to the template surface, other objects may be deformed during the folding process (these objects are called passive objects). Passive objects may be any node−based geometric objects. They are folded on a per−node basis parallel to the defined slip system.

We calculate the initial slip system based on the geometry of the template surface and the direction of the unfolding plane. The algorithm passes a vertical slice that is parallel to the unfolding plane through each node within the 3−D model, and the intersection line of the vertical slice with the template surface is calculated.

Dip−domain boundaries for the template intersection line are then calculated (Figure 2). This defines the geometry of the slip system for that particular node. This procedure is then iteratively applied to each node on the geological objects selected to be unfolded to the target geometry. This procedure simulates flexural flow (Ramsay & Huber, 1987) parallel to the template surface. The final slip system is calculated based on the geometry of the target surface using a similar procedure (Figure 2).

The folding algorithm preserves several aspects of the 3−D model:
1. line length of the template surface in the orientation of the unfolding direction
2. line lengths of surfaces parallel to the template surface in the unfolding direction
3. thickness orthogonal to the template surface
4. volume of the folded objects
5. cross−sectional area in the orientation of the unfolding direction.
These constraints are maintained whether there is constant or variable shortening along the strike of a fold.

Flexural restoration process

Once the slip system has been defined, each object (i.e., the template surface and the passive objects) is systematically restored. The initial position of each node within each object is determined by its relative position with respect to the template surface, the unfolding plane and the position of the node along the sinuous length of the slip system.

The node positions are defined by the *sth* local coordinate system (Figure 2):
s: The distance from the node to the pin surface as measured along the node’s slip system line. This sinuous distance is defined by the intersection of the template surface and a vertical slice through the node parallel to the unfolding plane (Figure 2).
t: The orthogonal distance of the node from an arbitrary, fixed position vertical unfolding plane (i.e., in and out of the page in Figure 2). The *t* value forms a relative 3−D coordinate system that retains on which vertical slice a given node is located.
h: The orthogonal distance of the node from the template surface. This distance is defined by the intersection of the template surface and the unfolding plane at the location of a node (Figure 2). All nodes are located within a dip domain as dip−domain boundaries are defined as being infinitely thin.

This *sth* value for the node defines where the final folded position of the node lies within the target slip system. To calculate this final position, the slip system for the target surface is calculated the same way as for the template surface. The node is placed within the target slip system such that the values for *s*, *t*, and *h* are maintained, defining its new geometry (Figure 2).

Benefits of the restoration technique

The key difference between this technique and previous flexural unfolding methodologies is that object restoration is performed on a per−node basis while maintaining the node connectivity during the folding process.

Previous techniques using triangulated surfaces divided the surfaces into separate triangles, unfolded each triangle to a datum, and then packed the triangles together using a fitting algorithm (e.g., Gratier et al., 1991; Gratier & Guillier, 1993; Williams et al., 1997; Rouby et al., 2000). These processes required that each surface be unfolded separately, without explicitly preserving volume or maintaining flexural−flow linkage between the surfaces. In contrast, our restoration technique maintains node connectivity throughout the restoration, allowing volumes containing multiple surfaces to be restored in a single operation.

Because the technique does not require triangle fitting, strains that are generated during the restoration process can be analysed in a geological context. Our technique also provides advantages over previous inversion schemes for searching for an optimal transformation from one folded state to another (e.g., Leger et al., 1997). Specifically, the calculated slip system explicitly preserves:
1. line length in the orientation of the unfolding plane of the template surface
2. thickness orthogonal to the slip system;
3. line length in the unfolding direction of surfaces parallel to the template surface, and
4. volume of the folded objects.

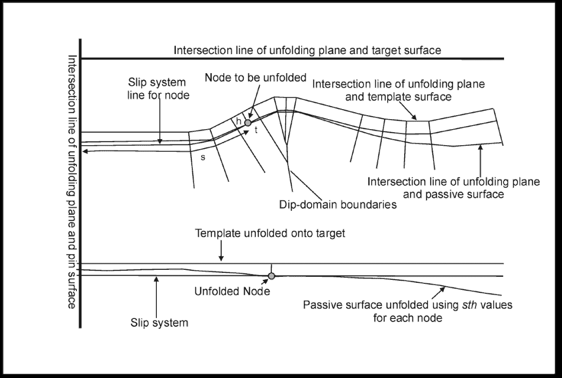

Figure 2. Node−based slip system determination and folding process. Slip system values are determined for each node to be deformed. A vertical slice in the orientation of the unfolding plane through the node is calculated. The slip system through the node is defined parallel to the intersection line of the template surface and the unfolding plane. From this, the node values in the slip system, sth, are determined. The node is transferred to the new position by maintaining the sth values for the node transformation.

Midland Valley
Software and Consulting