Automatic Recognition and Resolution of Line Symbol Spatial Conflict in Cartography Based on Elastic Beams Model

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1 Symbol conflict

The space conflicts in cartography refer to the inconsistent of the space relationship between the geographical entities and symbol objects because of the space targets and the relationship between the targets do not meet the spatial integrity constraints. From the destructive point view , there are three categories symbol conflict: spatial conflict, visual conflict and relationship conflict(LI et al., 2006). Space conflicts and visual conflict are the main conflict between line symbols in the national basic scale topographic map. Weibel and Buttenfield's(Weibel and Buttenfield, 1988) research proves that displacement is the primary mean to solve the symbol conflict and keep the space relationship between features clearly.

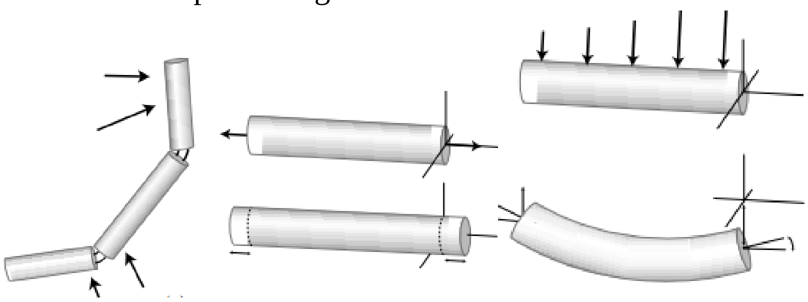
Many scholars have conducted many research in the detection and processing of line symbols, such as Straight Road Point Shit Method(Lichtner, 1979), Road Smooth Movement Algorithm taking into road intersections(Nickerson, 1988), a method based on raster data(Jäger, 1991), Spring Model(Bobrich, 1996), Snake Model(Burghardt and Meier, 1997), a algorithm based on finite element(Hojholt, 1998), Elastic Beams Method(Bader, 2001), a method based on Constrained Delaunay Triangulation(Jones et al., 1995) (Ruas, 1998), Global Adjustment Method based on geometry, topology restrictions(Harrie, 1999), Object Group Movement Method based cluster analysis, Building Groups Movement based on Field Theory(Ai, 2004) and Vector and Raster Mixed Movement Algorithm(LI et al., 2006).

The symbol conflict in topographic map is the main form of error of map information expression because of the constraint relationship between symbols are destroyed. From the destructive point view , there are three categories symbol conflict: spatial conflict, visual conflict and relationship conflict. The main method to deal with symbol conflict is deformation and movement. Deformation and movement means that changing the position coordinates of some features to change features' geometric morphology or move the whole features.

2 Elastic Beams Model

Elastic Beams Model comes from the electrical engineering field. Bader(Bader, 2001) introduced the method into the cartographic generalization movement application. This method is based on the energy minimization idea. The internal energy comes from the geometric characteristics of the line feature, the out energy refers to the power of the external force applied to the feature.. When the internal energy and external energy reach an equilibrium, the deformation of the line feature is optimal and feature's movement is also the best. The line segment between two adjacent point of one feature could be considered as a beam according to the finite element theory. If there are n point in a feature, this feature could be considered as a combination of n-1 beams (Figure 1 (a)). So the deformation of the feature could be expressed by every beam's deformation.

For one single beam, the external force could be divided normal force and tangential force. The normal force is along the middle line of the feature and the tangential force is perpendicular to the feature. The deformation of a feature along the middle line is stretching or compression under normal force(Figure 1 (b)), the feature could bend under the tangential force(Figure 1 (c)). Both the stretching, compression and bend could generate potential energy. The external force could completely convert to he internal potential energy in the ideal state. But in fact, the power of the external force is less than the internal potential energy, because energy could be consumed in the deformation processing due to the resistance or other factors.



(a) (b) (c)

Figure 1. (a) Elastic Beams of a feature; (b) stretching or compression deformation along the middle line direction; (c) bending deformation perpendicular to the feature.

Strain energy would be generated in the deformation process. The external stress is positively correlated to the strain energy. If the deformation distance is named *x* in the external stress *F*, the strain energy *U* is calculate by equation 1:

$$U = \int_0^x F d_x \tag{1}$$

3 deformation and movement

Elastic Beam Model is a energy minimization curve model, external energy promotes the deformation of the feature and internal energy control the shape the curve. There are two main methods to study the model's effect and role in line symbol deformation and shit. Firstly, we could investigate the effect of internal energy without considering external force. Secondly, we can also impose external force on certain point to study the effect of external force on deformation and shit of features.

3.1 considering only internal energy

If there is not any external force, all elements in vector f equals to 0, the equation *Kd=f* could be simplified as *Kd=0*. With different boundary conditions, deformation and shit could be carried out in different conditions.

As shown in Figure 2, maintain the starting point or end point, move the other one. The blue line stands for the original position of the feature, arrow shows the movement vector, the red line indicates the final position of the line feature after deformation.

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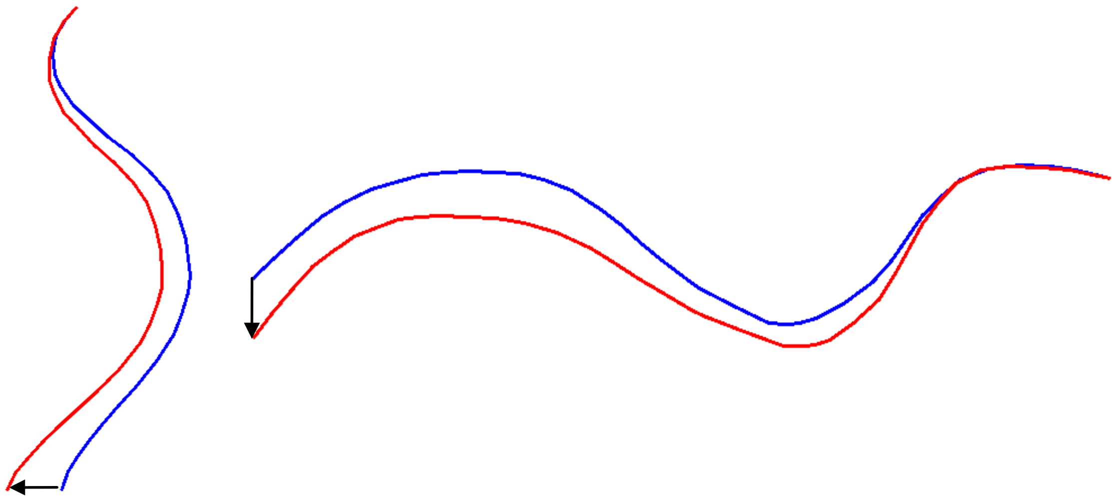


Figure 2. Deformation with fixed starting or end point of line features.

If the staring point and end point are both fixed, only move one point in the feature, the deformation is shown in Figure 3.

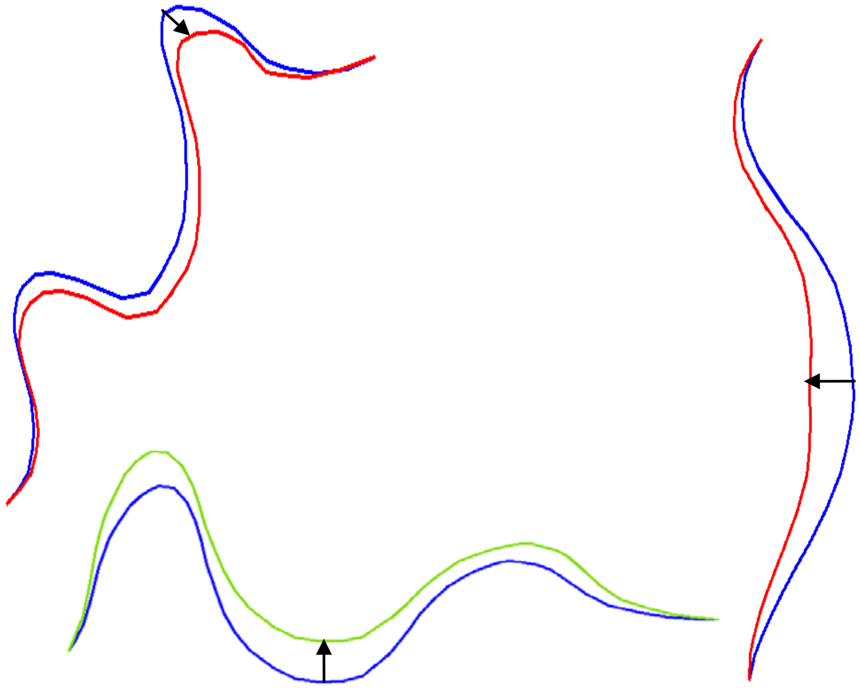


Figure 3. Deformation with fixed both starting and end point of line features, only move one point in the feature. The blue line stands for the original position of the feature, arrow shows the movement vector, the red line indicates the final position of the line feature after deformation.

If the staring point and end point are both fixed, move two points in the feature, the deformation is shown in Figure 4.

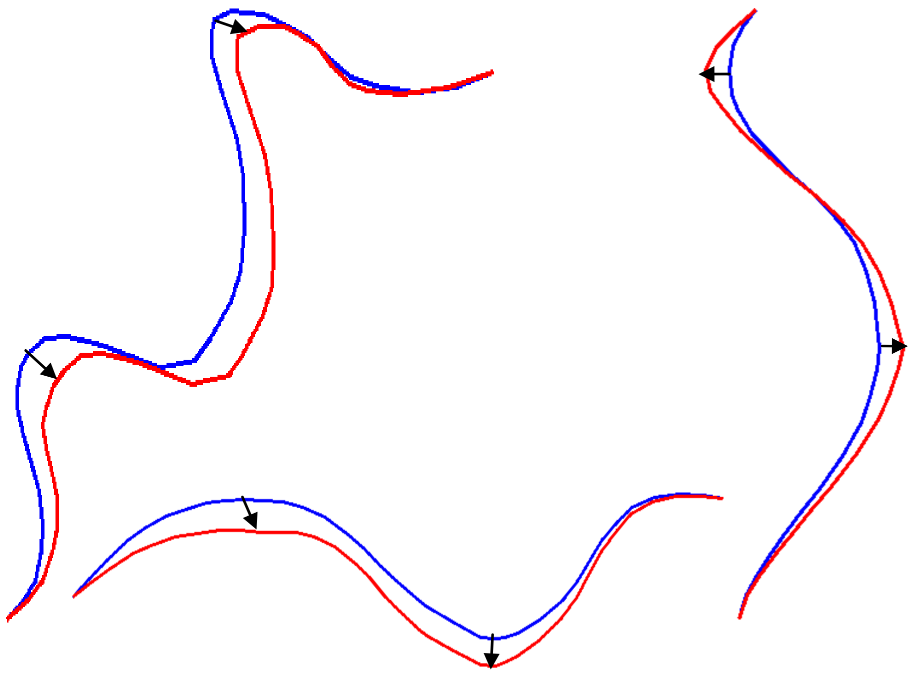


Figure 4. Deformation with fixed both starting and end point of line features, move two points in the feature. The blue line stands for the original position of the feature, arrow shows the movement vector, the red line indicates the final position of the line feature after deformation.

As shown in Figure(2, 3 4), the energy definition in the Elastic Beam Model is rationality, and the deformation in the model could keep the original shape of the line feature.

3.2considersing both internal energy and external energy

There are two line features named A and B. The point P is in the line feature A, and the point Q is the point that he distance between the points in line feature B and P is the shortest. The distance from P to the line feature B is $dis = |QP|$. r stands for the width of the two line symbol, d_{min} is the minimal recognition distance. The distance between P and B must be longer than r. The external force imposed on P from the line feature B is calculated by equation 2:

$$f = \frac{QP}{|QP|}\left(r - \min\left(dis, r\right)\right) \tag{2}$$

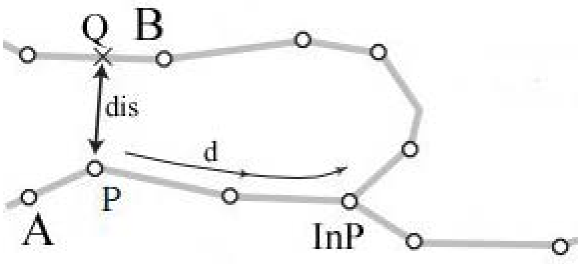
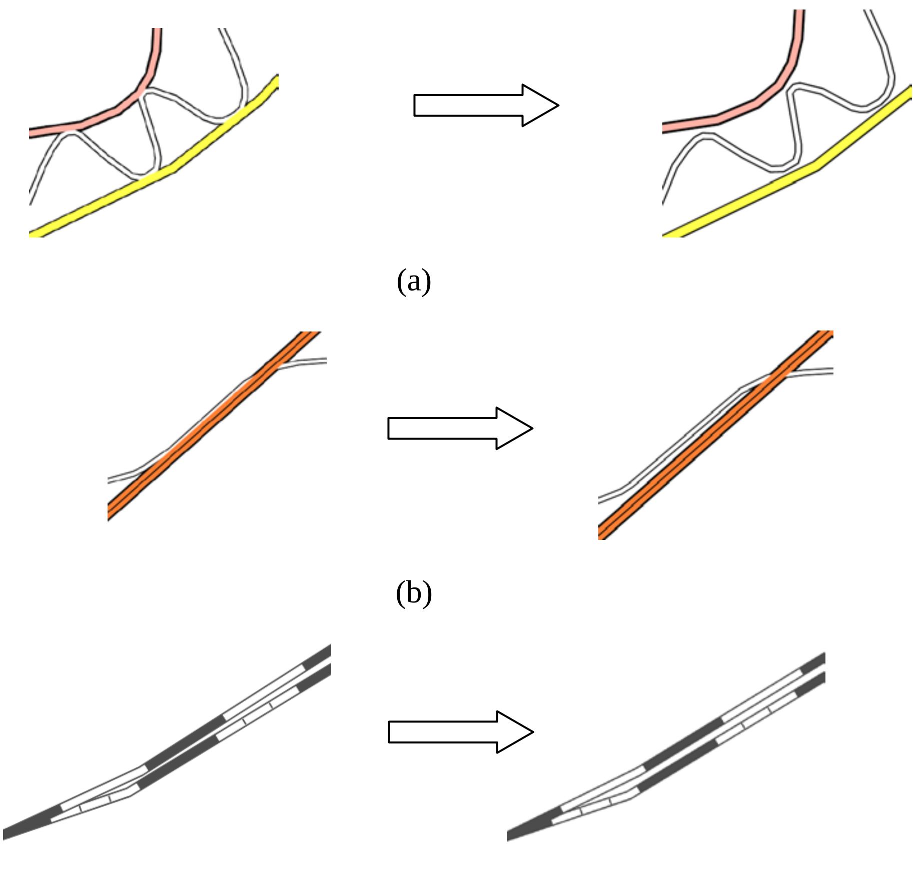


Figure 5. Diagram of force imposed on the feature

Assume that there are n features impose external force on the node P, the force vector could be represented as $v_1, v_2, ..., v_n$, the aggregate external force which node P suffers could be calculated by formula 3, where $\frac{v_i}{|v_i|}$ represents the direction of force, the formula in parentheses stands for the size of the force. The node P will be affected by external forces when the distance from node P to a line feature.

$$f_P = \sum_{i=1}^{n} \frac{v_i}{|v_i|}\left(r - \min\left(|v_i|, r\right)\right) \quad (3)$$



(a)

(b)

(c)

Figure 6. Single road deformation results

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