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Approximate Method for Forming Double Belt Lattice Structures

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ABSTRACT

The question of controlling the geometric parameters of the polyline is considered. A static-geometric method is given for transforming the original polyline by moving the node under various geometric conditions.

KEYWORDS: *statics, knot, design, modeling, discrete.*

Introduction

Geometric techniques are used to change the original polyline while accounting for the various design constraints. Different formulations of discrete modelling issues are brought about by a wide range of discrete models for surfaces and curved lines, as well as numerous variations in design specifications.

The following may be one of the design requirements: create a starting polyline that represents a curve. The given polyline must be changed into a new one so that the angles between its adjacent links match a set of predetermined values.

By moving the original polyline's knots, one potential transformation of the original polyline can be offered. The movement of a polyline node can be visualized as any directional motion by a vector, the start of which corresponds to the knot's initial location and the end of which corresponds to the knot's final position.

We may categorise the potential moving methods into two groups based on the examination of the current design criteria and the relationship between the position parameters of the knots on the initial and produced polylines:

1. The directions of knot displacement vectors do not depend on the shape of the initial polyline and are determined at the stage of problem statement.
2. The directions of the displacement vectors are quantities that depend on the shape and position parameters of the polyline and cannot be determined in advance.

The displacement vectors' directions are specified in the first scenario. Knots, for instance, can only travel vertically. As a result, there is just one parameter that influences the knots' position.

The issue is more challenging in the second scenario since it is unknown which way the knot will move when it moves. A one-parameter set of knot positions with a specific value of angle α_i at the vertex are defined by a pair of neighboring knots. It is important to impose an additional condition that binds this parameter in order to find a single place. Such circumstances could exist in:

1. Ensuring equality of bond lengths.
2. Maintaining the regularity of the position of the knots of the polyline.
3. Maintaining the ratio of the lengths of adjacent links, etc.

In accordance with this, the process of changing the adjacency angles of the links of a polyline (AAL) can take place under the following geometric conditions:

1. The pitch of the knots of the polyline (for example, along the *0x* axis) and the lengths of its links change.(fig.1,a).
2. The lengths of the links of the polyline change while the pitch of the knots remains unchanged.(fig.1 ,b).
3. The pitch of the knots changes while the length of the links remains unchanged (fig.1,c).
4. Knot pitch and link lengths remain unchanged (fig.1d,)

The disadvantages of the geometric method of controlling the initial polyline proposed above are, first of all, a significant dependence of the number of iterations on the number of knots of the polyline (and, therefore, a multiple step-by-step search, which slows down the solution process), and secondly, a number of restrictions imposed to ensure the convergence of the process.

The application of the static-geometric approach to solve this problem allows us to get rid of these drawbacks. In this case, the solution is also iterative, but the angles are not controlled sequentially from one node to another, but simultaneously for all knots of the polyline (when solving a system of linear equations).

In the static-geometric method, the above problems are solved by moving the original knots under the action of some conditional forces. In this case, the forces determined for each knot are substituted into a system of linear equilibrium equations of the form:

$k\sum_{i=1}^{n}(u_i^t - u_0^t) + \sum_{t=1}^{n} P_i + Q - kT = 0,$ *(1)*

where $\boldsymbol{T}$ – Static interpretation of the requirement to the system.

The projection of vector **T** on the coordinate axes is determined by the formula:

$kT_{u,i}^{t+1} = 2u_i^t$ - $u_{i,1}^t$ -u_{i+1}^t *(2)*

where $\boldsymbol{u}$ – generalized coordinate notation;

$\boldsymbol{i}$ – knot numbers;

$\boldsymbol{k}$ – aspect ratio;

$\boldsymbol{t}$ – ordinal step of the iterative refinement process.

Consider solving some problems, statically and geometrically. Let it be required to ensure that the values of the angles of adjacent links (AAL) are equal to a given value with simultaneous equalization of the lengths of the links (Fig. 1). The conditional forces that move the source knots to the desired position are determined by substituting values. (2) and (3) c (1).

$$x_H = [(x_C - x_A)^2 x_B + (y_C - y_A)^2 x_A + (x_C - x_A)(y_C - y_A)(y_B - y_A)](l_{AC})^{-2}$$

$$y_H = [(x_C - x_A)^2 y_A + (y_C - y_A)^2 y_B + (x_C - x_A)(y_C - y_A)(x_B - x_A)](l_{AC}),^{-2} \quad (2)$$

$$x_i = \frac{x_{i-1} + x_{i+1}}{2} - \{(y_{i+1} - y_{i-1})(x_{i-1}y_{i+1} - x_{i+1}y_{i-1}) + (x_{i+1} - x_{i-1})[x_i(x_{i+1} - x_{i-1}) + y_i(y_{i+1} - y_{i-1})] - x_i\}\left\{l_{i-1}^{i+1} \pm \left[(1 + tg^2\alpha_0)\left(l_{i-1}^{i+1}\right)^2\right]^{\frac{1}{2}}\right\}(2tg\alpha_0 l_i^H)^{-1} \quad (3)$$

$$y_i = \frac{y_{i-1} + y_{i+1}}{2} - \{(x_{i+1} - x_{i-1})(x_{i+1}y_{i-1} - y_{i+1}x_{i-1}) + (y_{i+1} - y_{i-1})[x_i(x_{i+1} - x_{i-1}) + y_i(y_{i+1} - y_{i-1})] - y_i\}\left\{l_{i-1}^{i+1} \pm \left[(1 + tg^2\alpha_0)\left(l_{i-1}^{i+1}\right)^2\right]^{\frac{1}{2}}\right\}(2tg\alpha_0 l_i^H).^{-1}$$

To apply this method, we need to consider the equilibrium of a single knot of the polyline.

Suppose that for the polyline ABCDE it is necessary to provide equality of angles of adjacent links according to the required graph of values, while at the same time equalizing the lengths of links converging at the knots.

In this case, the knot is in equilibrium (Fig. 1) under the action of the following forces:

1. Effort in the links

$P_{AB} = k(u_A - u_B);\ P_{AB} = k(u_A - u_B);$ (4)

In the desired position, the knot must also be in equilibrium. The forces acting on the knot:

1. In Connections

$\bar{P}_{AB}^0 = k(u_A - u_B^0);\ \bar{P}_{CB}^0 = k(u_C - u_B^0).$ (5)

2. Holding the knot in a new position when the angle between the ties is $\boldsymbol{\alpha_B}$ and $\boldsymbol{AB_0 = B_0C}$

$$kT_{x,B} = \{(y_A - y_C)(x_Ay_c - x_Cy_A) + (x_A - x_C)[x_B(x_C - x_A) + y_B(y_C - y_A)] + x_B\}\left\{l_{AC} \pm [(1 + tg^2\alpha_B)l_{AC}^2]^{\frac{1}{2}}\right\}(tg\alpha_B l_{BH})^{-1}$$

$$kT_{y,B} = \{(x_A - x_C)(x_Cy_A - x_Ay_C) + (y_A - y_C)[x_B(x_C - x_A) + y_B(y_C - y_A)] + y_B\}\left\{l_{AC} \pm [(1 + tg^2\alpha_B)l_{AC}^2]^{\frac{1}{2}}\right\}(tg\alpha_B l_{BH})^{-1} \quad (6)$$

where $\boldsymbol{kT_{x,B}}$, $\boldsymbol{kT_{y,B}}$ - the projections of the force $\boldsymbol{kT}$ applied at knot B, respectively on the ***x***-axis, ***y***-axis;

$$\boldsymbol{l_{AC}} = |[(x_A - x_C)^2 + (y_A - y_C)^2]^{\frac{1}{2}}|\ ;$$

$$\boldsymbol{l_{BH}} = |[(x_B - x_H)^2 + (y_B - y_H)^2]^{\frac{1}{2}}|\ ;$$

The coordinates of the knot ***H*** are determined from the relations:

$x_H = [(x_C - x_A)^2x_B + (y_C - y_A)^2x_A + (x_C - x_A)(y_C - y_A)(y_B - y_A)](l_{AC})^{-2}$

$y_H = [(x_C - x_A)^2y_A + (y_C - y_A)^2y_B + (x_C - x_A)(y_C - y_A)(x_B - x_A)](l_{AC}).^{-2}$ (7)

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Equations (6) for an arbitrary knot in the indices of the reference system have the form:

$$kT_{x,i}^{t+1} = \{(y_{i-1}^{t} - y_{i+1}^{t})(x_{i-1}^{t}y_{i+1}^{t} - y_{i-1}^{t}x_{i+1}^{t}) + (x_{i-1}^{t} - x_{i+1}^{t})[x(x_{i+1}^{t} - x_{i-1}^{t}) + y_{i}^{t}(y_{i+1}^{t} - y_{i-1}^{t})] + x_{i}^{t}\}\left\{l_{i-1}^{t,i+1} \pm \left[(1 + tg^{2}\alpha_{B})(l_{i-1}^{t,i+1})^{2}\right]^{\frac{1}{2}}\right\}\left(tg\alpha_{0}l_{i}^{t,H}\right)^{-1};$$

$$kT_{y,i}^{t+1} = \{(x_{i-1}^{t} - x_{i+1}^{t})(x_{i+1}^{t}y_{i-1}^{t} - y_{i+1}^{t}x_{i-1}^{t}) + (y_{i-1}^{t} - y_{i+1}^{t})[x_{i}^{t}(x_{i+1}^{t} - x_{i-1}^{t}) + y_{i}^{t}(y_{i+1}^{t} - y_{i-1}^{t})] + y_{i}^{t}\}\left\{l_{i-1}^{t,i+1} \pm \left[(1 + tg^{2}\alpha_{0})(l_{i-1}^{t,i+1})^{2}\right]^{\frac{1}{2}}\right\}\left(tg\alpha_{0}l_{i}^{t,H}\right)^{-1}; \quad (8)$$

Based on these dependencies we build an iterative algorithm for the statistical-geometric method of forming a polyline with equal angles of adjacent links (AAL) and paired equal links.:

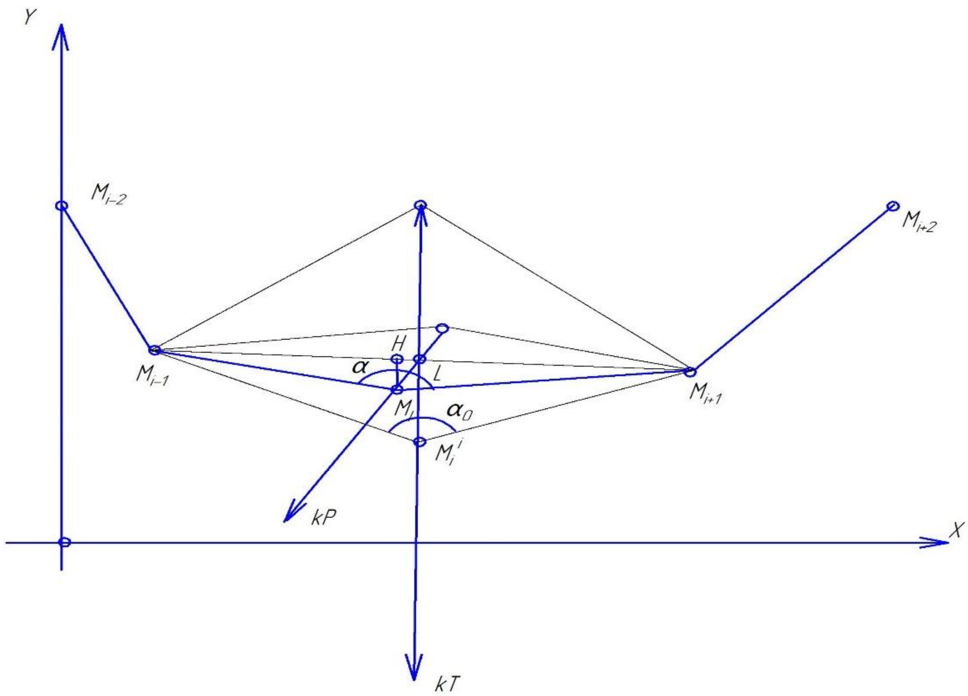

Рис. 1. Равенство углов смежных звеньев.

1. Determine parameters of the knots of the first approximation of the polyline.
2. Based on the coordinates of the knots of the first Italian polyline, the projections of the conditional forces ***kT*** for each of the loose knots are determined.
3. The values of ***kT*** are supplied in equations of the form (1), which are composed for the coordinates ***x*** and ***y***.
4. The systems of equations (1) are solved together, as a result of which the coordinates of the knots of the new approximation are determined.
5. Similarly to the geometric method, the quality of the solution is evaluated by comparing it with the given values of $\boldsymbol{\delta_i}$ and $\boldsymbol{S_i}$. If the check is positive, the iteratory process is terminated. If it is

not. – continues. The data of the last decision are taken as new input data and the process is repeated, starting from point 2.

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