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A SIMULATION OF CAT'S CRADLE BY GEOMETRICALLY NONLINEAR ANALYSIS WITH SLIDING NODES

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There already exist many studies about geometrically non-linear analysis of cable structures. Cables have sag under gravity, and do not have stiffness against compressional strain. In general, catenary cable elements[1] or truss elements with hyperbolic stiffness[2] to describe behaviour of cables. Furthermore, for example, in case of deformation analysis for catwalk nets of tensegrity structure and so on, contact behaviour between cables should be evaluated. Therefore, we have to consider two different types of nonlinearity simultaneously. Previously, there are some studies about contact and sliding of cable elements. (for example[3])

Authors have been investigated geometrical nonlinearity of soft structures such as thin frames cables, and membranes using the tangent stiffness method. The method has two major characteristics. One is that the unbalanced forces are calculated using the strict compatibility between nodal displacements and element edge deformations, and the other is that the geometrical stiffness is completely separated from elements' own stiffness. Therefore, converged solutions are in perfect equilibrium state and computational process is so rapid as well as Newton Raphson method. Namely, the method has a different idea from the general type of FEM, which has geometrical stiffness formulated form nonlinear strain and shape functions.

In this study, a new type of element which can treat frictionless contact by involving slide nodes is proposed, and numerical examples simulate process of cat's cradle which is very popular game among kids as "AYATORI" also in Japan. Cat's cradle has so many complex procedures including contact, sliding and separation, and computation by general type FEM will be very tough. Therefore, the success of cat' cradle simulation by the tangent stiffness method shall suggest the advantage of the tangent stiffness method, and possibility of usage on the method for strong and complex nonlinear problem will be expected.

Figure1 shows a numerical example and photos corresponding to each process. In this example, a cable element with hyperbolic stiffness connects edge node1 and edge node5 via node2,3,4 which are intermediate sliding nodes. Also, node2 and node3 are the elastic supports which simulate the passive movement of fingers. At first, node4 approaches toward the string 1-2 [A]-[C], and it goes down. Then, the contact phenomenon occurs and new sliding nodes6 and 7 are generated [D]. Further, nodo8 has been generated as a control point between node6 and 7, then node8 moves toward opposite direction[E]-[G]. Finally, node8 goes up as shown in [H].

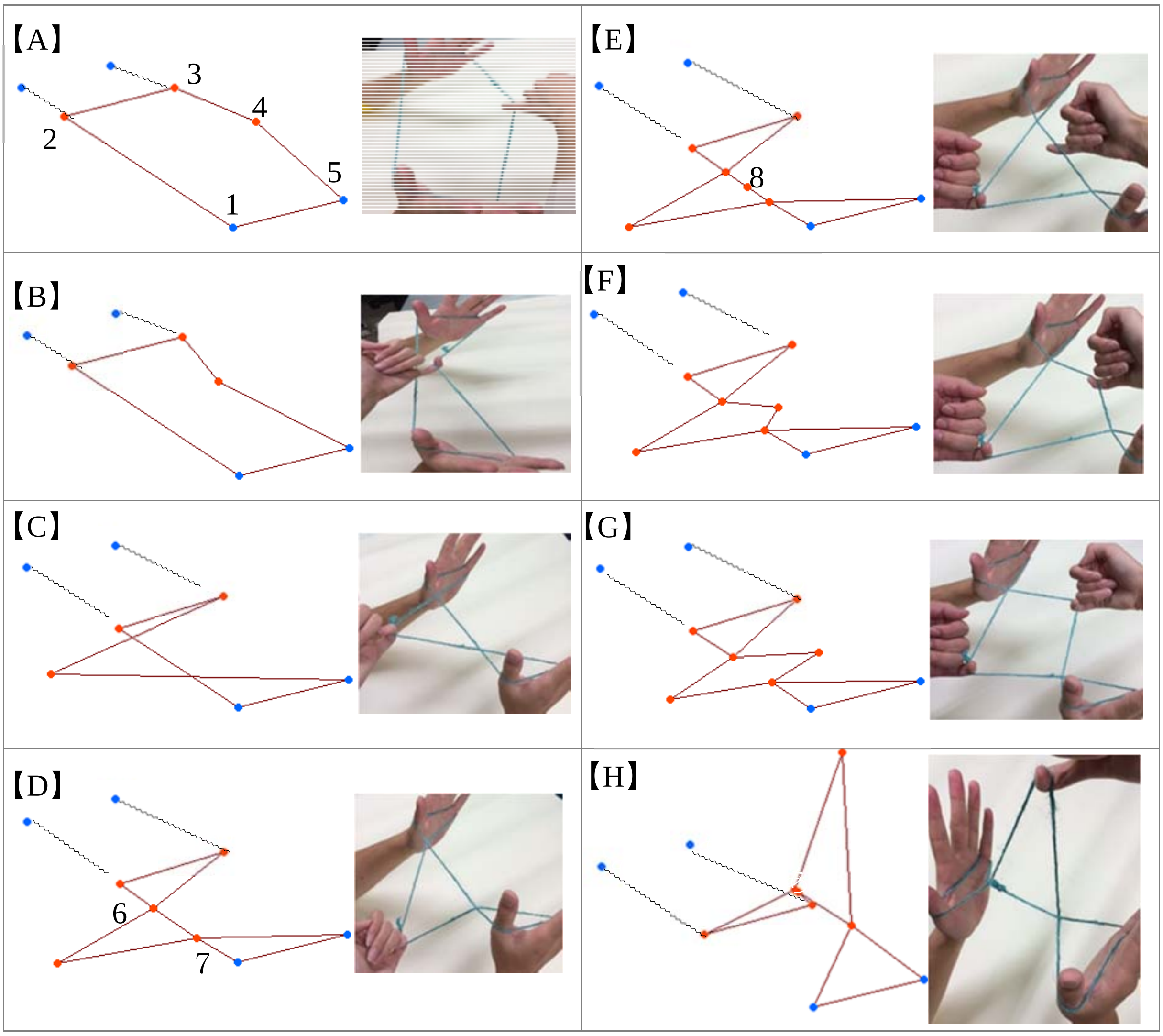

Figure1 A simulation of cat's cradle

As shown in Figure1, the proposed cable elements gives strict equilibrium solutions with the tangent stiffness method, even if in case of tough compound nonlinear situation. On the conference site, much more examples will be shown.

[1] S. Goto, Tangent stiffness equation of flexible cable and some considerations, *Journal of JSCE*, Vol. **270**, pp. 41–49, 1978.
[2] Y.Inukai, A. Kimura, F.Fujii and H. Noguchi, Computational Techniques for Flexible and Incompressive Nets, *Journal of Structural Engineering, JSCE,* Vol.50A, pp.151-156, 2003.
[3] B. Zhou, M.L. Accorsi *, J.W. Leonard, Finite element formulation for modelling sliding cable elements, *Computers and Structures 82*, pp.271–280, 2004.