SHAPE CONTROL OF HIGH DEGREE-OF-FREEDOM VARIABLE GEOMETRY TRUSSES

By

R. J. Salerno, C. F. Reinholtz, and H. H. Robertshaw
Virginia Polytechnic Institute and State University
Blacksburg, Virginia

ABSTRACT

Common static trusses are constrained to permit no relative motion between truss elements. A Variable Geometry Truss (VGT), however, is a truss which contains some number of variable length links. The extensible links allow the truss to change shape in a precise, controllable manner. These changes can also be used to control the vibrational response of a truss structure or to perform robotic tasks.

Many geometric configurations, both planar and spatial, are possible candidates for VGT manipulators. For this presentation only two geometries will be discussed; the three degree-of-freedom (DOF) spatial octahedral/octahedral truss and the three DOF planar tetrahedral truss. These truss geometries are used as the fundamental element in a repeating chain of trusses. This results in a highly dexterous manipulator with perhaps 30 to 60 degrees of freedom that retains the favorable stiffness properties of a conventional truss. From a fixed base, this type of manipulator could perform shape or vibration control while extending and "snaking" through complex passageways or moving around obstacles to perform robotic tasks.

In order for this new technology to be useful in terms of robotic applications the forward and inverse kinematic solutions must be efficiently solved. The approach taken here is to first concentrate on fully understanding the forward and inverse kinematics of the fundamental elements and then utilizing the insight thus gained to solve the more complex problem of the kinematic chains. The inverse solution of a 30 DOF planar manipulator will be discussed. The discussion will focus on how to specify parameters for an underspecified system by using shape control algorithms.

Shape Control of High Degree-of-Freedom Variable Geometry Trusses

Robert J. Salerno
Babu Padmanabhan
Charles F. Reinholtz
Harry H. Robertshaw

Variable Geometry Trusses

Definition

In simple terms a VGT is a statically determinant truss which contains some number of variable length members.

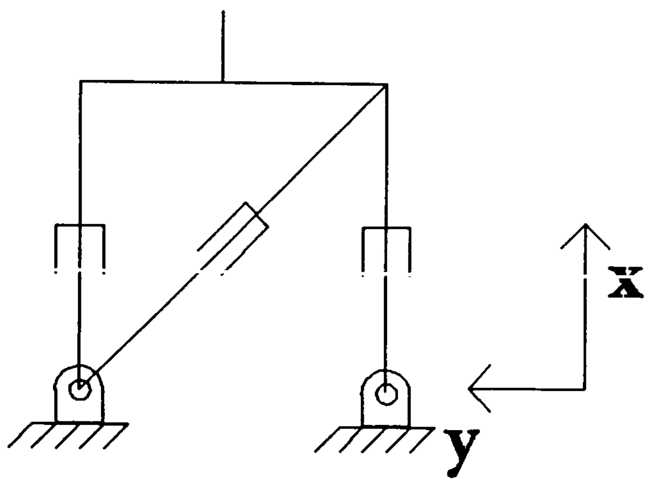
Variable Geometry Trusses

<u>Characteristics</u>

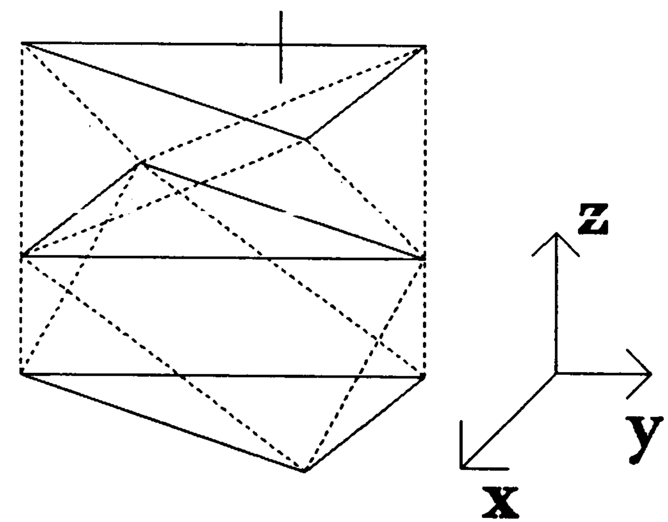
- Composed entirely of two force members (pure tension/compression)
- Excellent stiffness to weight ratio
- Number of DOF is equal to the number of extensible links

Two Candidate Geometries

Planar(2-D)
Tetrahedral Truss



Spatial(3-D)
Octahedral truss



Kinematics

The study of constrained motion of interconnected rigid links.

"Motion" includes position, velocity, acceleration and all higher derivatives.

Planar VGT Manipulator Kinematics

Forward Kinematics

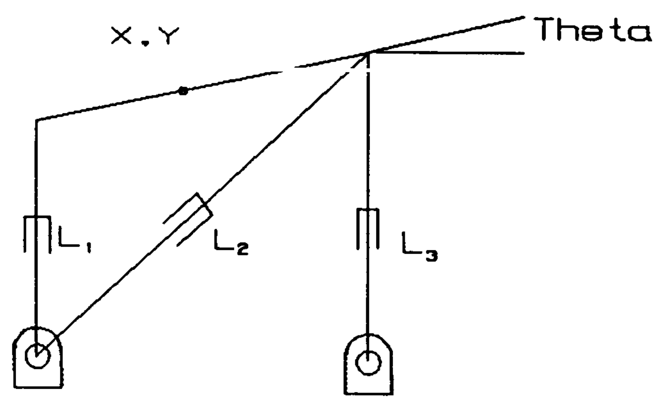
Given: L_1, L_2, L_3

Find: X, Y, Theta

Inverse Kinematics

Given: X, Y, Theta

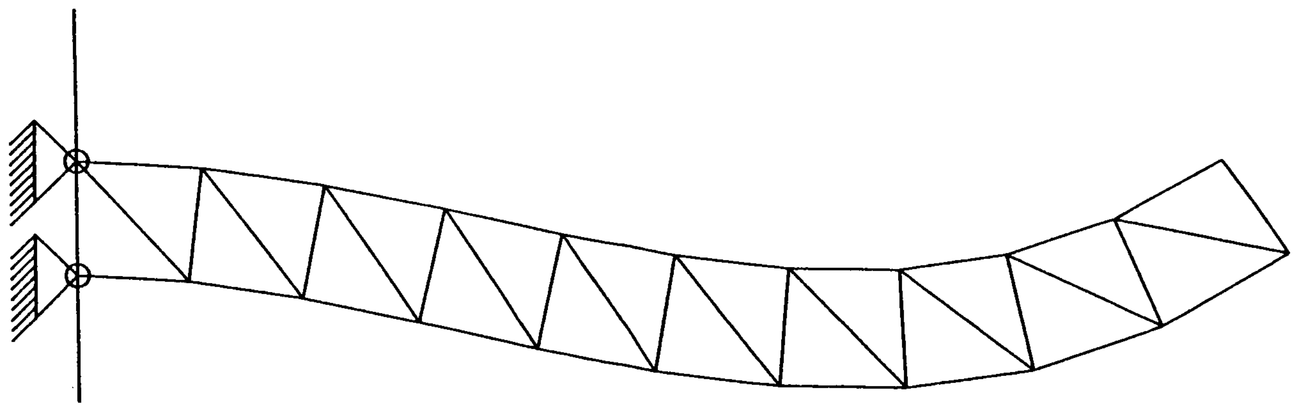
Find: L_1, L_2, L_3



Chaining n-Bays of Planar VGT's Together

- Extended range
- More degrees-of-freedom (Dexterity)

- Must specify 3n parameters (27 Free choices)



The Position Control Problem

How to specify 3(n-1) free choices?

Curve Fitting Approach

<u>Goal</u>

- To specify some minimum number of parameters which determines the truss shape

Input only the three end parameters, X, Y, and Theta, and have an algorithm which assigns the other 27 variables in some systematic manner.

The Position Control Problem

$$F(X) = A_0 + A_1 X + A_2 X^2 + A_3 X^3$$

How to specify 3(n-1) free choices?

Curve Specification by Boundary Conditions

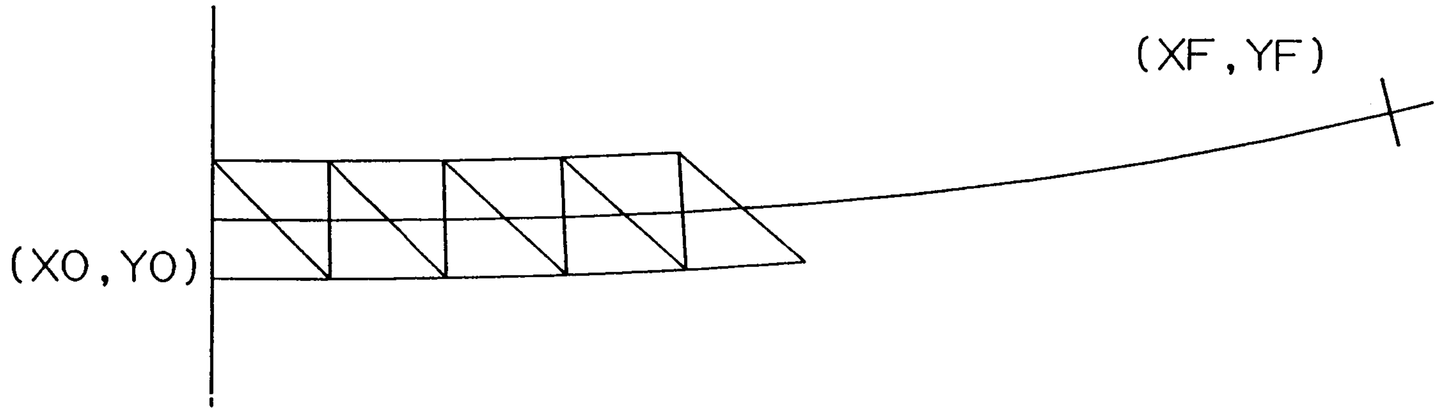
$$f(x_0) = a_0 + a_1 x_0 + a_2 x_0^2 + a_3 x_0^3$$

$$f'(x_0) = a_1 + 2a_2 x_0 + 3a_3 x_0^2$$

$$f(x_f) = a_0 + a_1 x_f + a_2 x_f^2 + a_3 x_f^3$$

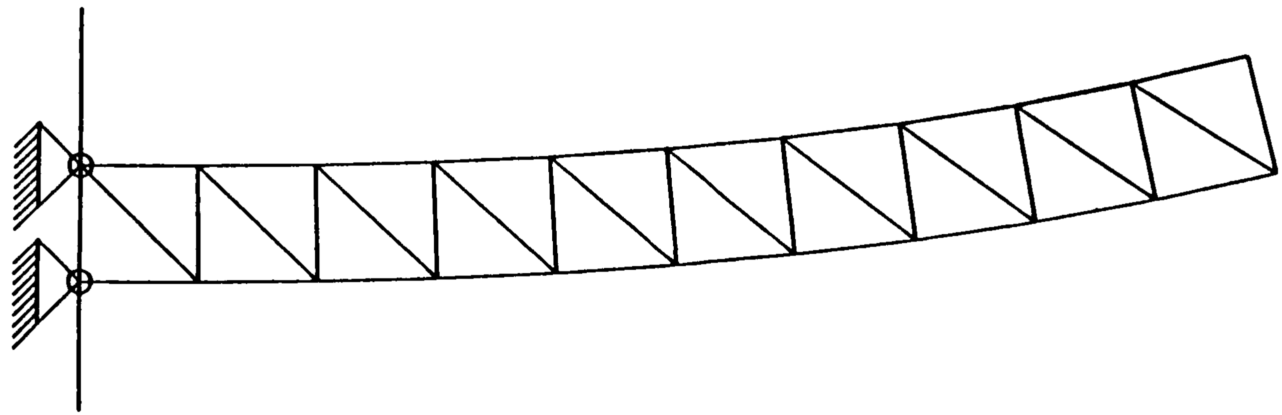
$$f'(x_f) = a_1 + 2a_2 x_f + 3a_3 x_f^2$$

Curve Partitioning



- Regular X spacing
- Regular arc length spacing
- Adaptable spacing

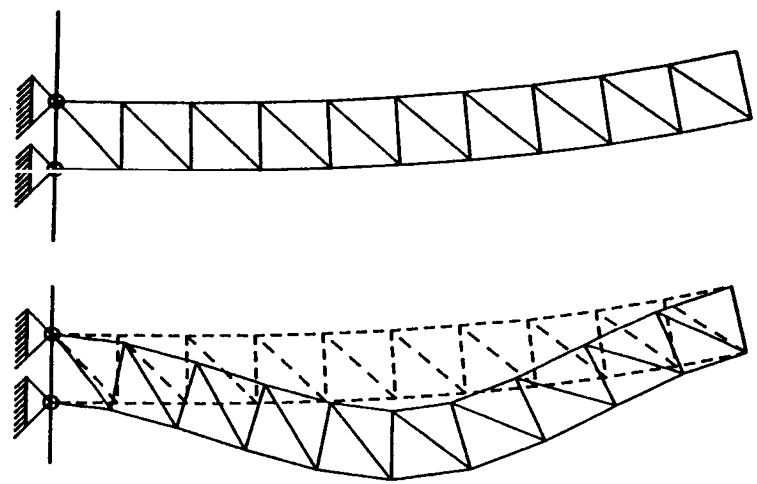
Results



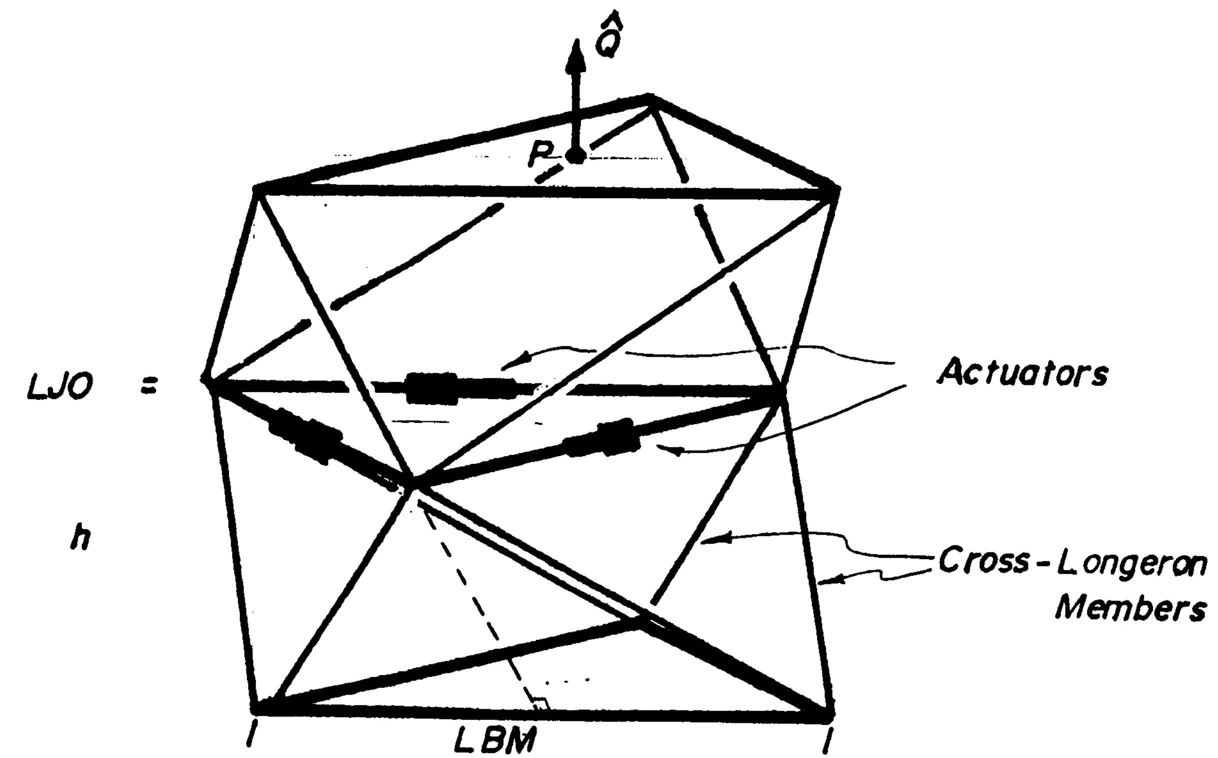
- Closed form solution
- Minimum input specification
- Parallel processing potential

Intermediate Shape Control

Specifying an alternative path while still minimizing input requirements.

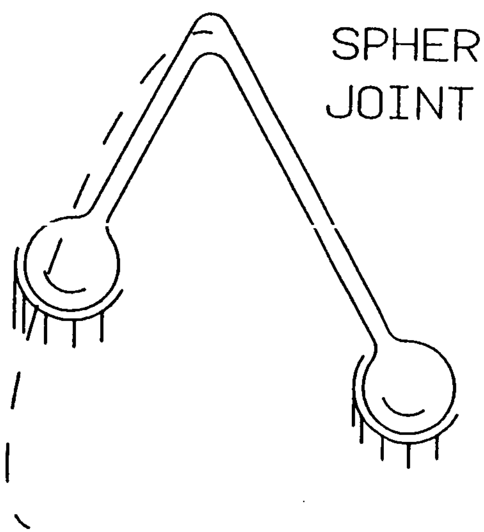


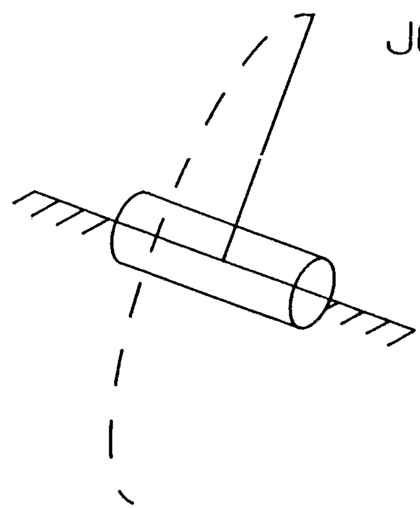
Spatial Octahedral Truss



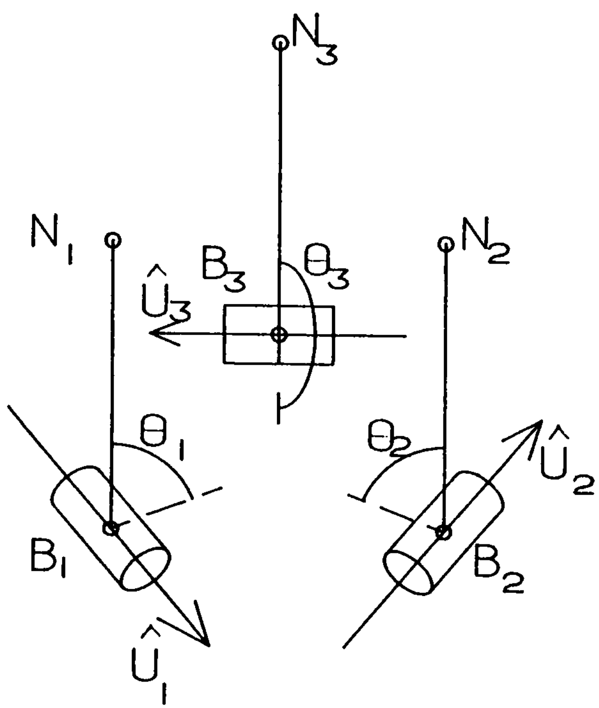
Spatial Truss Forward Kinematics

Employ the concept of kinematically equivalent devices





Lower Half of Spatial VGT



$$\underline{N}_I = \underline{B}_I + (R\theta_I, \hat{U}_I)\underline{H}_I$$

Constraint Equations

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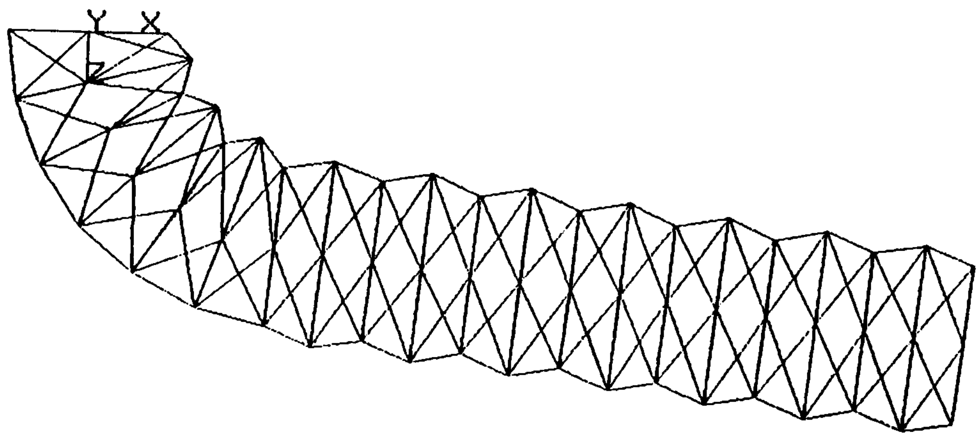
$$L_1 = \overline{n_1 n_2} = f(\theta_1, \theta_2)$$

$$L_2 = \overline{n_2 n_3} = f(\theta_2, \theta_3)$$

$$L_3 = \overline{n_3 n_1} = f(\theta_3, \theta_1)$$

$$0 = L - \sqrt{A\cos\theta_1 + A\cos\theta_2 + B\cos\theta_1 \cos\theta_2 - B\sin\theta_1 \sin\theta_2 + C}$$

Continuing Research



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