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EFFICIENT DEVELOPMENT OF CONTINUUM/COMPLIANT PLANAR LINKAGE MECHANISMS

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ABSTRACT

This paper presents a method to develop continuum/compliant mechanisms based on planar bar-node linkage precursors. The method takes as inputs the initial node positions and connectivity data of a given bar-node linkage and converts it into a continuum/compliant mechanism having the same targeted motion. The line bars of the given bar-node linkage are thickened into trapezoidal planar members and the nodes are thickened by introducing fillets at each intersection of bars. The thicknesses of the bars and the shape parameters of the fillets in the continuum/compliant linkage are optimized to obtain the same targeted motion of the given bar-node linkage while keeping stresses below a maximum allowable value. Each design generated during the optimization process is evaluated using finite element analysis. The present method allows for the synthesis of mechanisms having the following advantages over conventional bar-node linkages: 1) They do not require complex ball or pin joints; 2) they can be readily 3-D printed and size-scaled, and 3) they can be optimized to decrease stresses below a maximum allowable value. Furthermore, the method uses a relatively small number of optimization variables (thicknesses of the members, shape-parameters of the fillets), making it an efficient alternative to more complex and computationally intensive methods for synthesizing compliant mechanisms such as those incorporating topology optimization.

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NOMENCLATURE

A_{jk}	$\in \mathbb{R}$. $k = 1,2,3,4$. Tangent steepness coefficient at the corners of the j^{th} trimmed member
b_{jk}	$\in \mathbb{R}^3$. $k = 1,2,3,4$. Position vectors of the corners of the j^{th} untrimmed member
$\bar{b}_{jk}$	$\in \mathbb{R}^3$. $k = 1,2,3,4$. Position vectors of the corners of the j^{th} trimmed member
C	$m \times 2$ bar-node connectivity matrix
$c(\xi)$	$\in \mathbb{R}^3$. Parametric curve defining the shape of the fillets
$c_x(\xi)$	Component of $c(\xi)$ in the x-direction
$c_y(\xi)$	Component of $c(\xi)$ in the y-direction
$c'(\xi)$	$\in \mathbb{R}^3$. Derivative of a parametric curve with respect to ξ
$\hat{e}_z$	$\in \mathbb{R}^3$. Unit vector along the 3-direction
F	$\in \mathbb{R}^{n\times \max(r)}$. Matrix that orders nodes around a common node counter-clockwise with respect to the x-axis
$r(i)$	$\in \mathbb{R}$. Number of nodes connected to the i^{th} node through bars
h_{jk}	$\in \mathbb{R}$. $k = 1,2,3,4$. Length parameters of member j
l_j	$\in \mathbb{R}^3$. Vector along the centerline of member j
$\hat{l}_j^{\perp}$	$\in \mathbb{R}^3$. Unit vector along the thickness direction of member j
m	Number of members
n	Number of nodes
p_i	$\in \mathbb{R}^3$. Position vector of node i
s_d	Number of steps of deformation