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Analysis and Design of Closed-Loop Deployable Frame Structure

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Abstract

With the advancement of membrane/blanket technology as an alternative choice to the conventional solid panels deployment for assemblies such as solar arrays, solar sails and radar antennas, the need for new ultra-lightweight deployable frame design is rapidly growing. The demand requires the structure to be more robust, more reliable, have a higher payload-to-area ratio and easier to control. Answering the call is a frame structure consists of rigid bars and mechanical joints, which should ideally have only one uniquely defined mechanism and a relatively high packaging ratio.

Presented herewith is a systematic study of the kinematics of this family of structures in numerical way. We are able to reveal considerable insights of the structural mechanism which can be obtained through careful study of singular values and rank deficit of the kinematic matrix of a structure, from which issues important for design, such as sensitivity can be analysed. The study also enables the simulation of deployment of structure with certain degrees of manufacture imperfection where under rigid body hypothesis, has no mechanism.

Presented also is a novel deployable structure which belongs to a spatial over-constrained mechanical linkages family. Consisting of six bars, this structure can form an expanded quadrilateral rectangular frame and folded up to a compact bundle. Our analysis and experimental results both confirm that the structure has only one mechanism along its deployment path. The mechanism appears to be a favourable potential for deploying and supporting flexible active surface of solar/radar structures, as its two outer and opposite bars always remain parallel throughout the whole deployment process.

With the development of this analytical approach, considerable insights into the kinematic behaviour of spatial over-constrained linkages can be revised and analysed. It has also become possible to design assemblies with special properties, e.g. frame with some particular dimension or non-symmetry.