A VIRTUAL REALITY INTERFACE FOR THE DESIGN OF COMPLIANT MECHANISMS

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Goal

To develop an immersive interface and a design algorithm to facilitate the synthesis of compliant mechanisms from a user-centered design perspective

Traditional rigid body mechanism

Compliant mechanism

Motivation

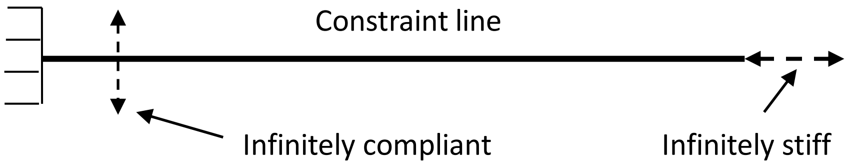
The three most common design methods for compliant mechanisms includes:

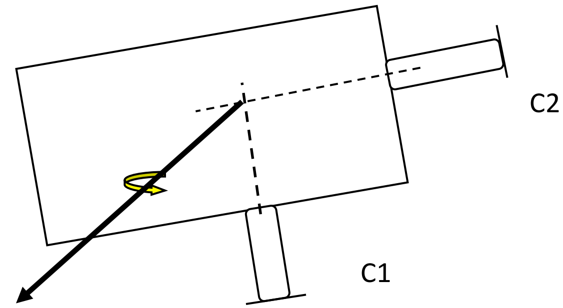
- topology optimization (Ananthasuresh GK, Kota S, Kikuchi N., 1994)
- pseudo-rigid body synthesis (Howell, L. L., and Midha, A., 1995)
- constraint-based approach (Maxwell, 1890; Blanding, 1999)

Each method has unique advantages and disadvantages.

This work focuses on developing a method that supports constraint-based design by providing the designer with an interface that connects the mathematics and the geometry of the design space.

Constraint-based method





Constraint-based method – mathematical basis

Twist: $\hat{T} = (\Omega : V) = (\omega s : c \times \omega s + v s) = (\omega s : c \times \omega s + p \omega s)$

Pure Rotation: $\hat{T} = (\omega s : c \times \omega s) \quad p = 0$

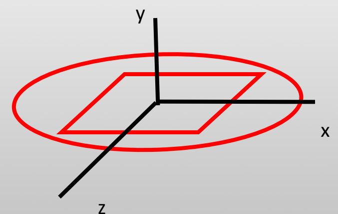
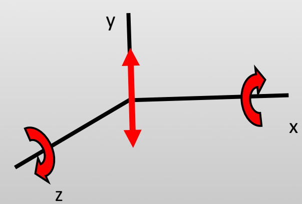
Pure Translation: $\hat{T} = (0 : v s) \quad p = \infty$

Wrench : $W^\wedge = (F \mid M) = (fu \mid r \times fu + mu)$

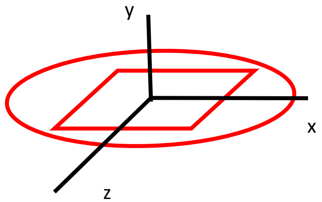
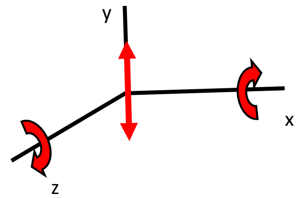
Pure force $(q = 0)$: $W^\wedge = (fu \mid r \times fu)$

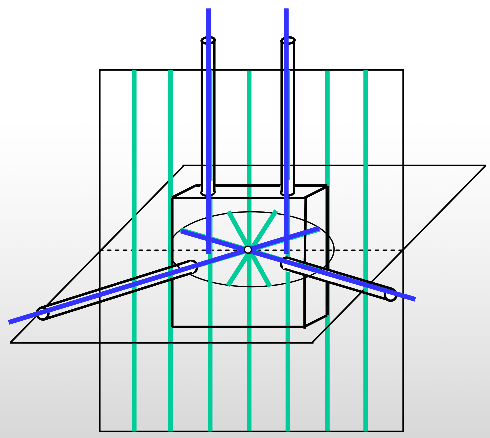
Pure couple $(q = \infty)$: $W^\wedge = (0 \mid mu)$

Constraint-based method – geometric representation

Freedom space in 3 orientations	Allowed motions
	

Approach

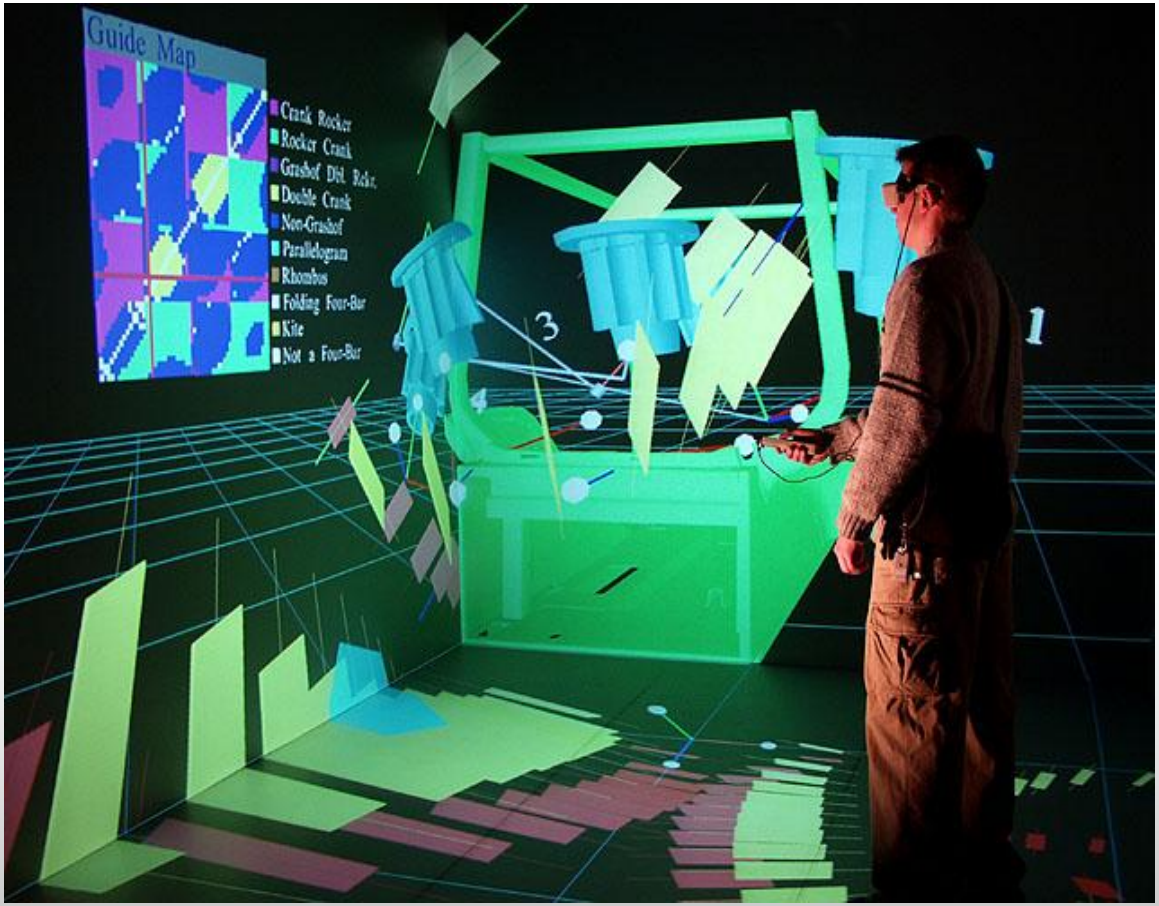
Freedom space in 3 orientations	Allowed motions	Twist representations
		$\begin{bmatrix}1\\0\\1\\0\\1\\0\end{bmatrix}$



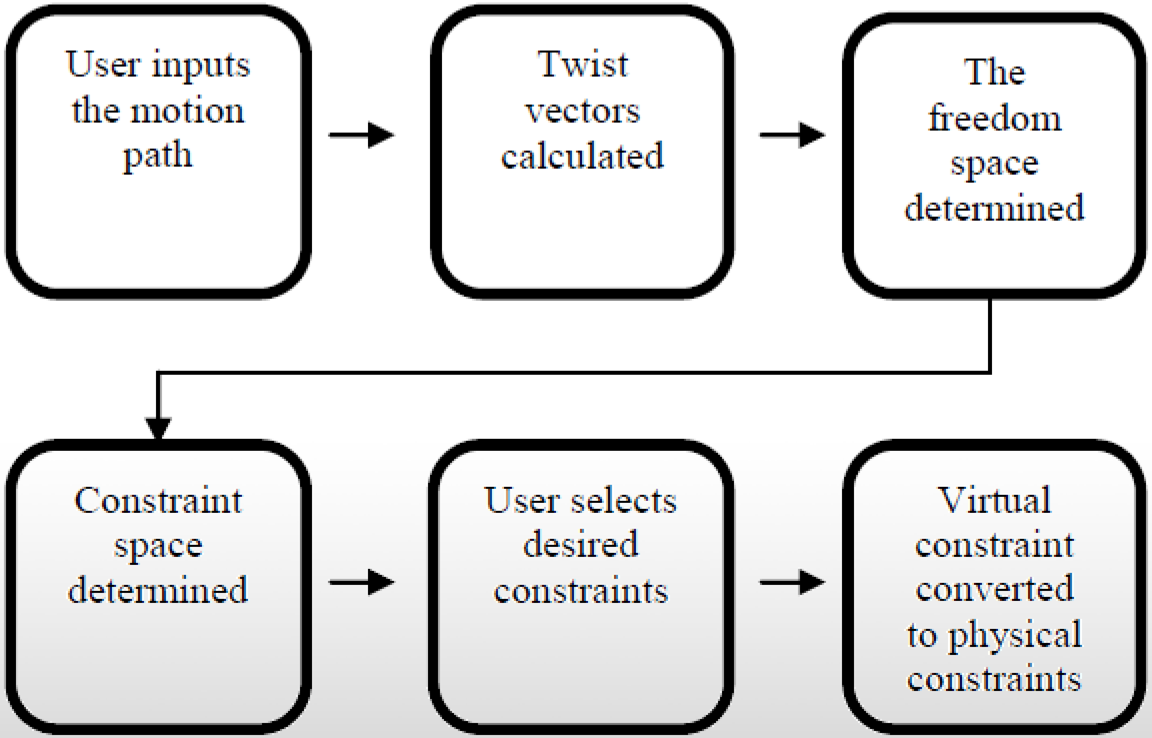
Approach

1. Allow the user to freely move a virtual object in 3D space to define the desired motion
2. Generate the associated geometric representation of the freedom space and constraint space using screw theory mathematics
3. Allow the user to select from all possible solutions
4. Generate the final design and allow the designer to evaluate the design in the 3D space

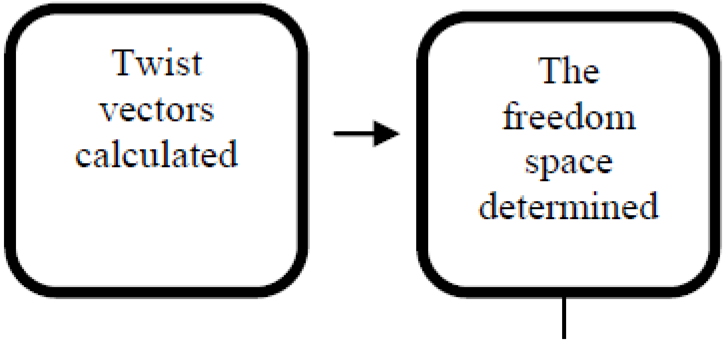
Virtual Reality



Methodology



Methodology

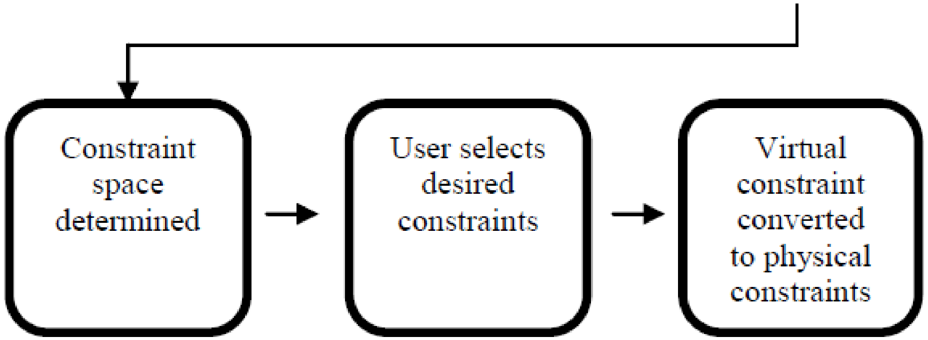


Catalogue of the twist vector representations of all the freedom spaces is pre-calculated and stored.

When the user defines a motion, the twist vector representations of those motions are calculated.

Algorithm checks the user motion representations against all the freedom spaces representations to determine the CASE and TYPE.

Methodology

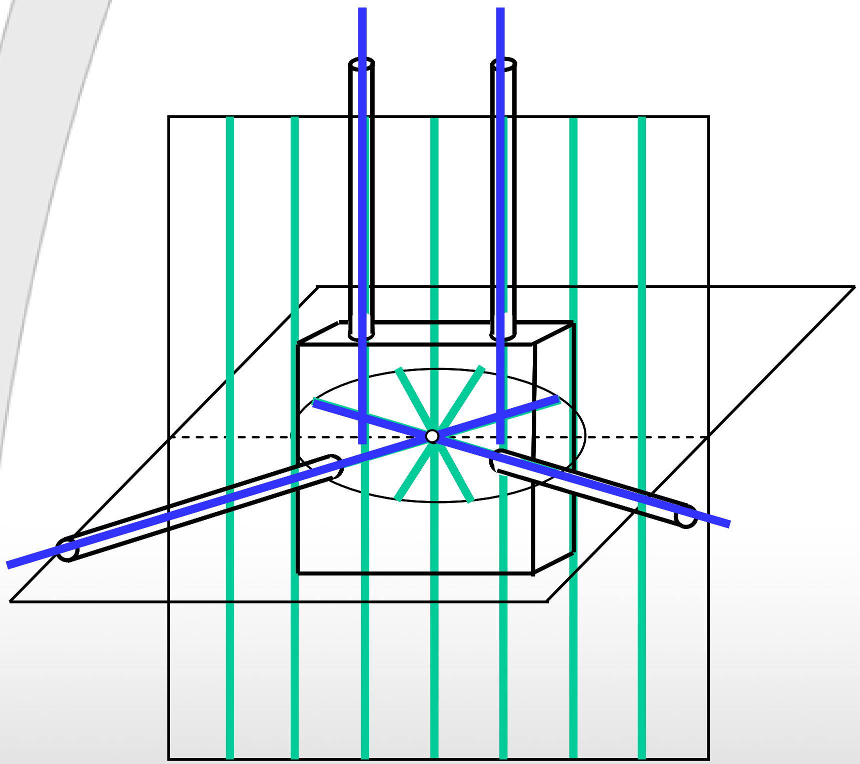


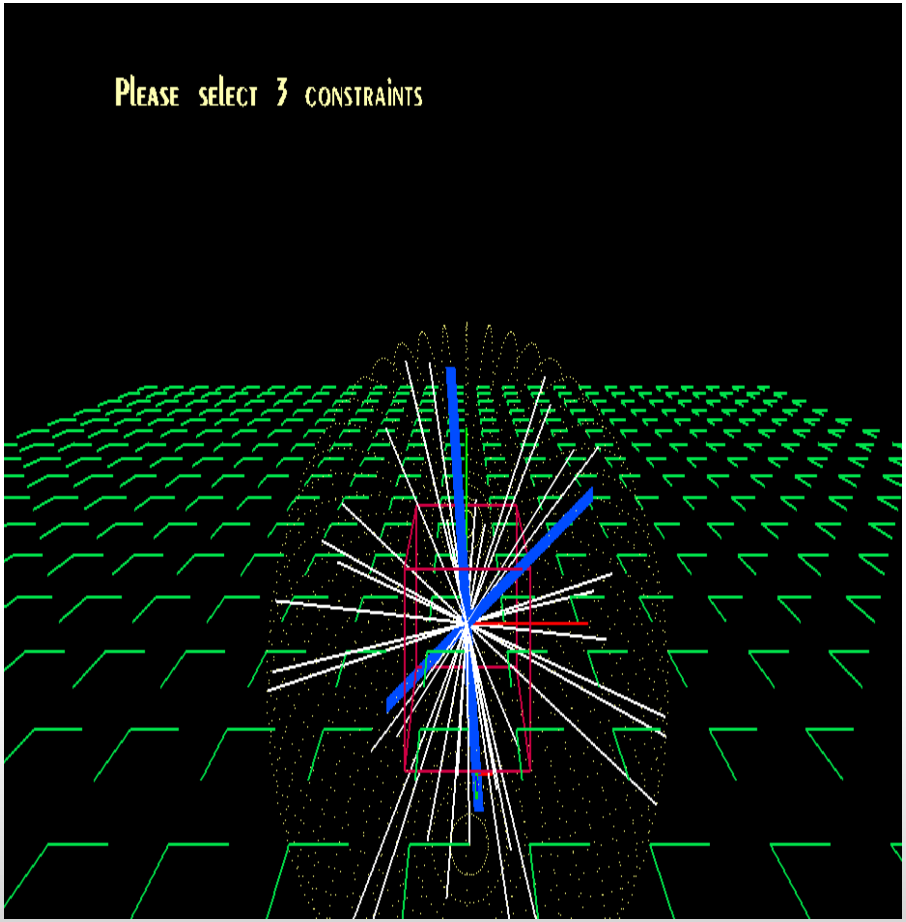
The unique constraint space is displayed to the user.

The user selects individual constraints from the possible set, and a mechanism is drawn.

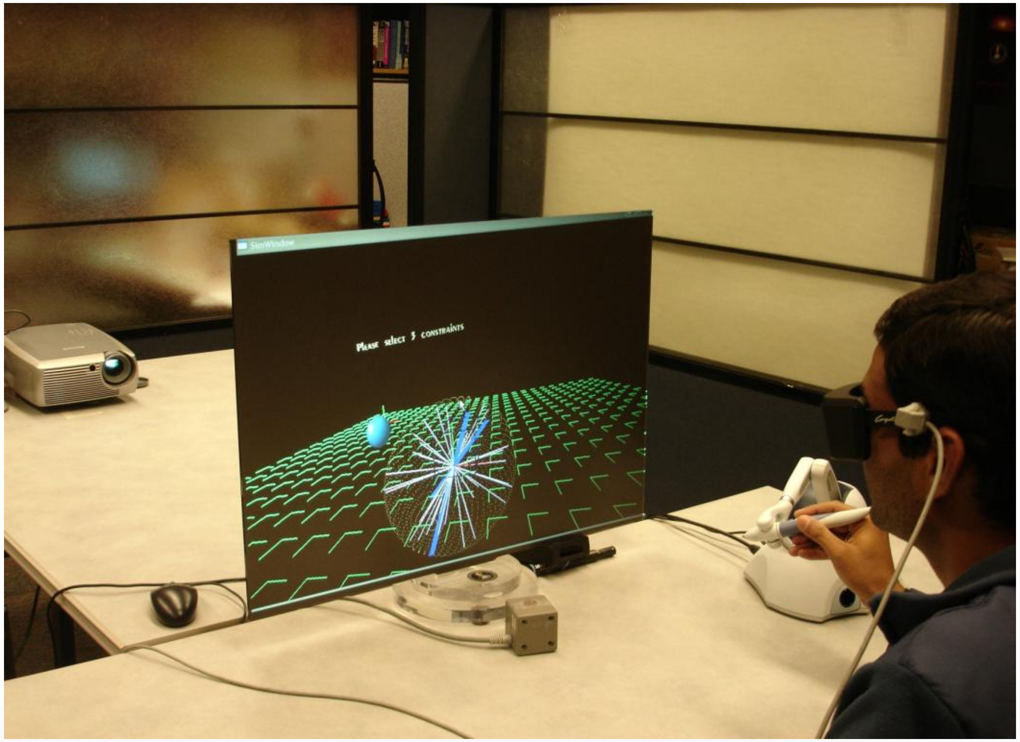
This iterative process proceeds to allow the designer to fully explore the potential solutions.

Example





Example



Conclusions

Our approach integrates FACT and screw theory and provides a user-centered approach for the design process.

A VR immersive interface is presented to the user which gives a natural way to design 3D mechanisms.

Future Work

Catalogue expansion

Support for motions not defined at orthogonal axes

Motion verification after the design

Acknowledgements

This work is supported through the National Science Foundation grant CMMI-0457041.

The authors specifically wish to acknowledge the support of our collaborator: Dr. Martin Culpepper (MIT) and his student, Jonathan Hopkins.

Su, H-J, Vance, J.M., Dorozhkin, D.V., “A Screw Theory Approach for the Type Synthesis of Compliant Mechanisms with Flexures”, IDETC 2009.