A graphical method of designing compliant mechanisms using the instant centre concept

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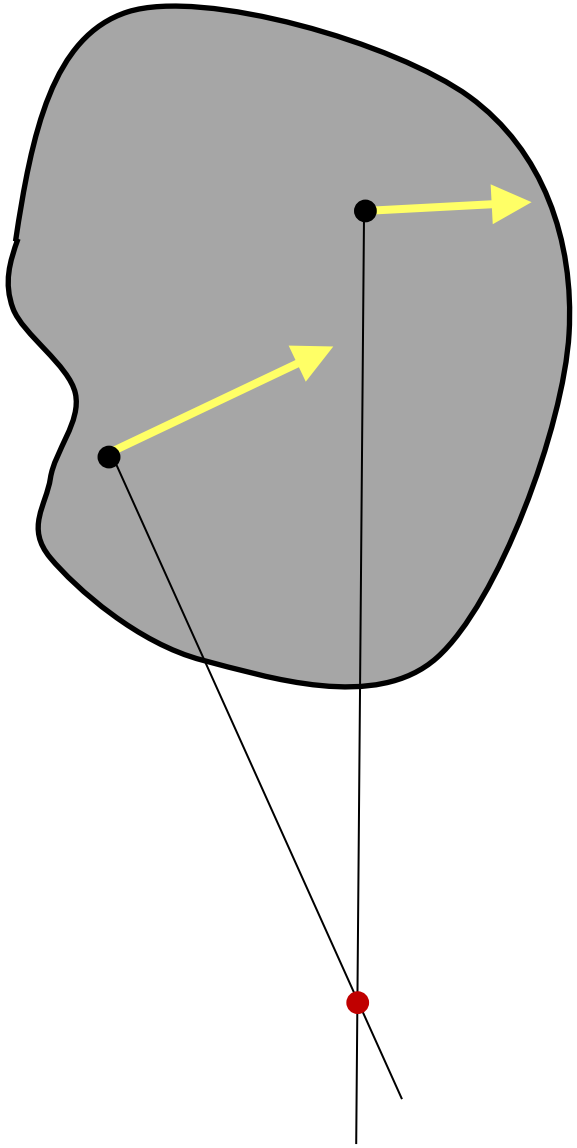
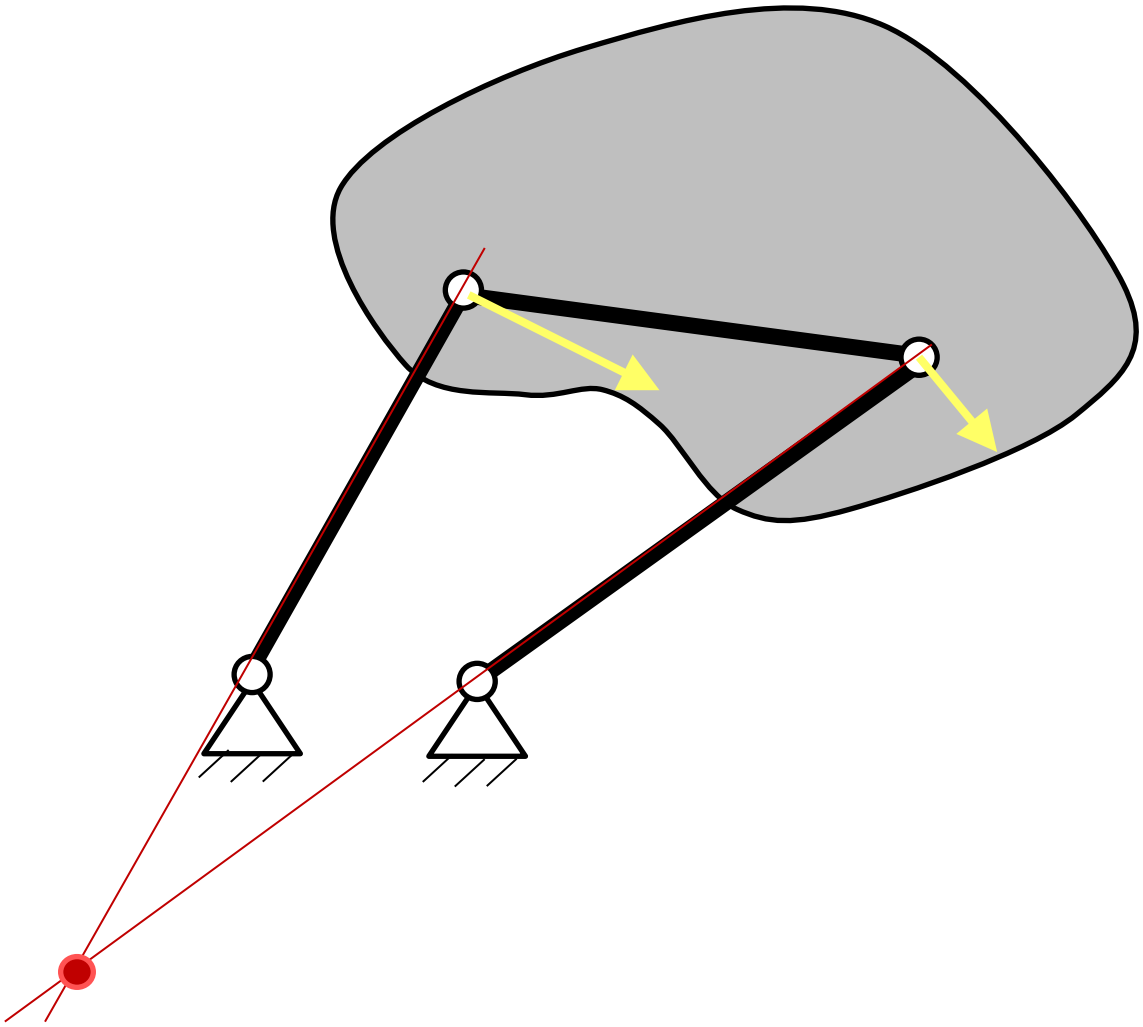
Instant centre of rotation



Instant centre for a four-bar linkage



Principal reference

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An Instant Center Approach Toward the Conceptual Design of Compliant Mechanisms

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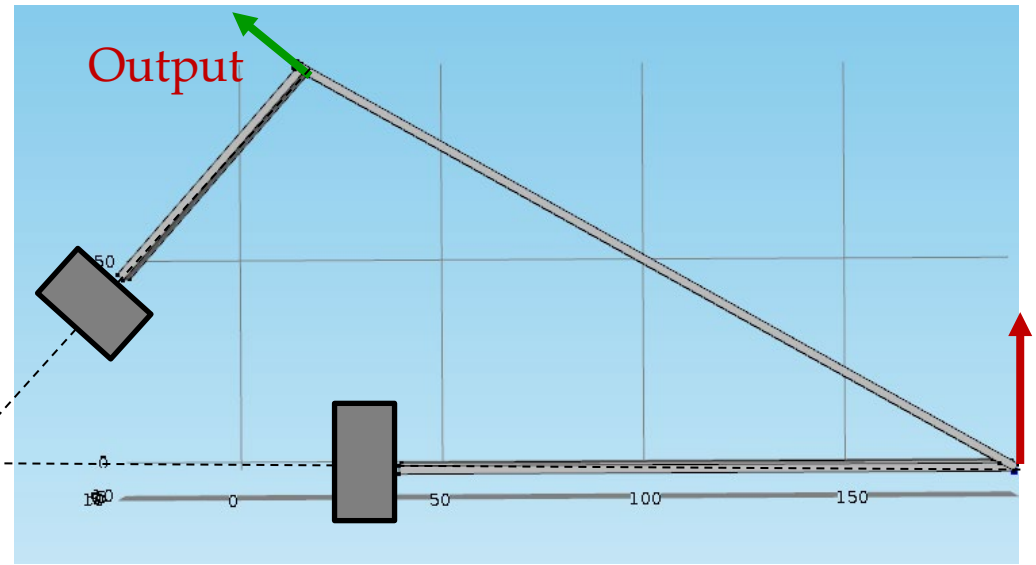
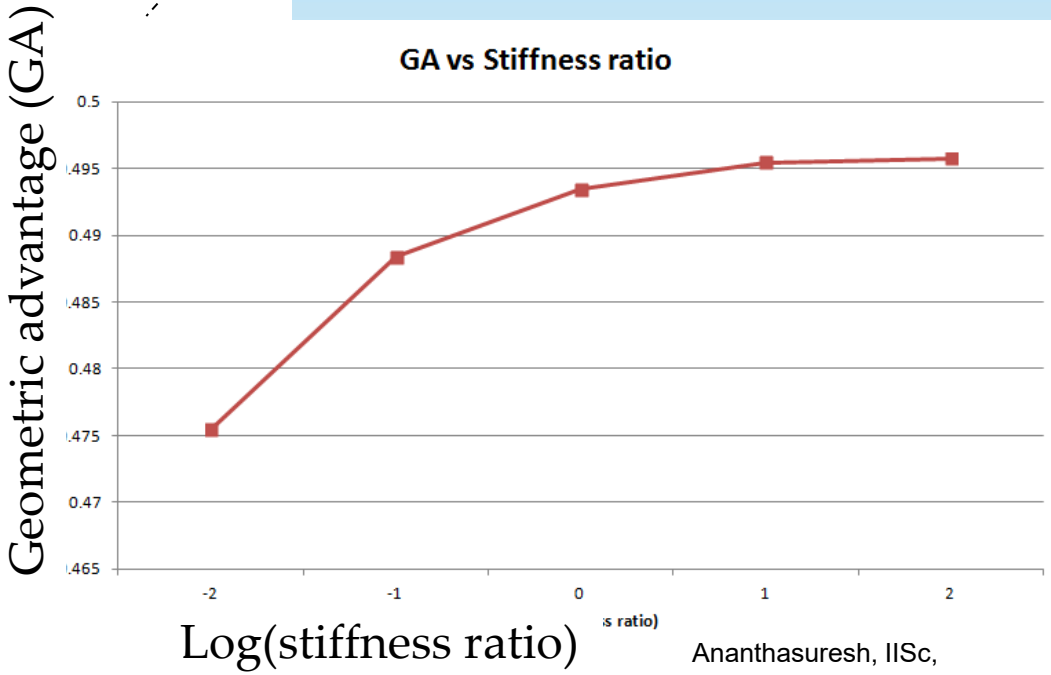
As with conventional mechanisms, the conceptual design of compliant mechanisms is a blend of art and science. It is generally performed using one of two methods: topology optimization or the pseudo-rigid-body model. In this paper, we present a new conceptual design methodology which utilizes a building block approach for compliant mechanisms performing displacement amplification/attenuation. This approach provides an interactive, intuitive, and systematic methodology for generating initial compliant mechanism designs. The instant center is used as a tool to construct the building blocks. The compliant four-bar building block and the compliant dyad building block are presented as base mechanisms for the conceptual design. It is found that it is always possible to obtain a solution for the geometric advantage problem with an appropriate combination of these building blocks. In a building block synthesis, a problem is first evaluated to determine if any known building blocks can satisfy the design specifications. If there are none, the problem is decomposed to a number of sub-problems which may be solved with the building blocks. In this paper, the problem is decomposed by selecting a point in the design space where the output of the first building block coincides with the second building block. Two quantities are presented as tools to aid in the determination of the mechanism's geometry – (i) an index relating the geometric advantage of individual building blocks to the target geometric advantage and (ii) the error in the geometric advantage predicted by instant centers compared to the calculated value from FEA. These quantities guide the user in the selection of the location of nodes of the mechanism. Determination of specific cross-sectional size is reserved for subsequent optimization. An example problem is provided to demonstrate the methodology's capacity to obtain good initial designs in a straightforward manner. A size and geometry optimization is performed to demonstrate the viability of the design. [DOI: 10.1115/1.2181992]

Keywords: compliant mechanisms, building block synthesis, instant center, conceptual design

Compliant four-bar block



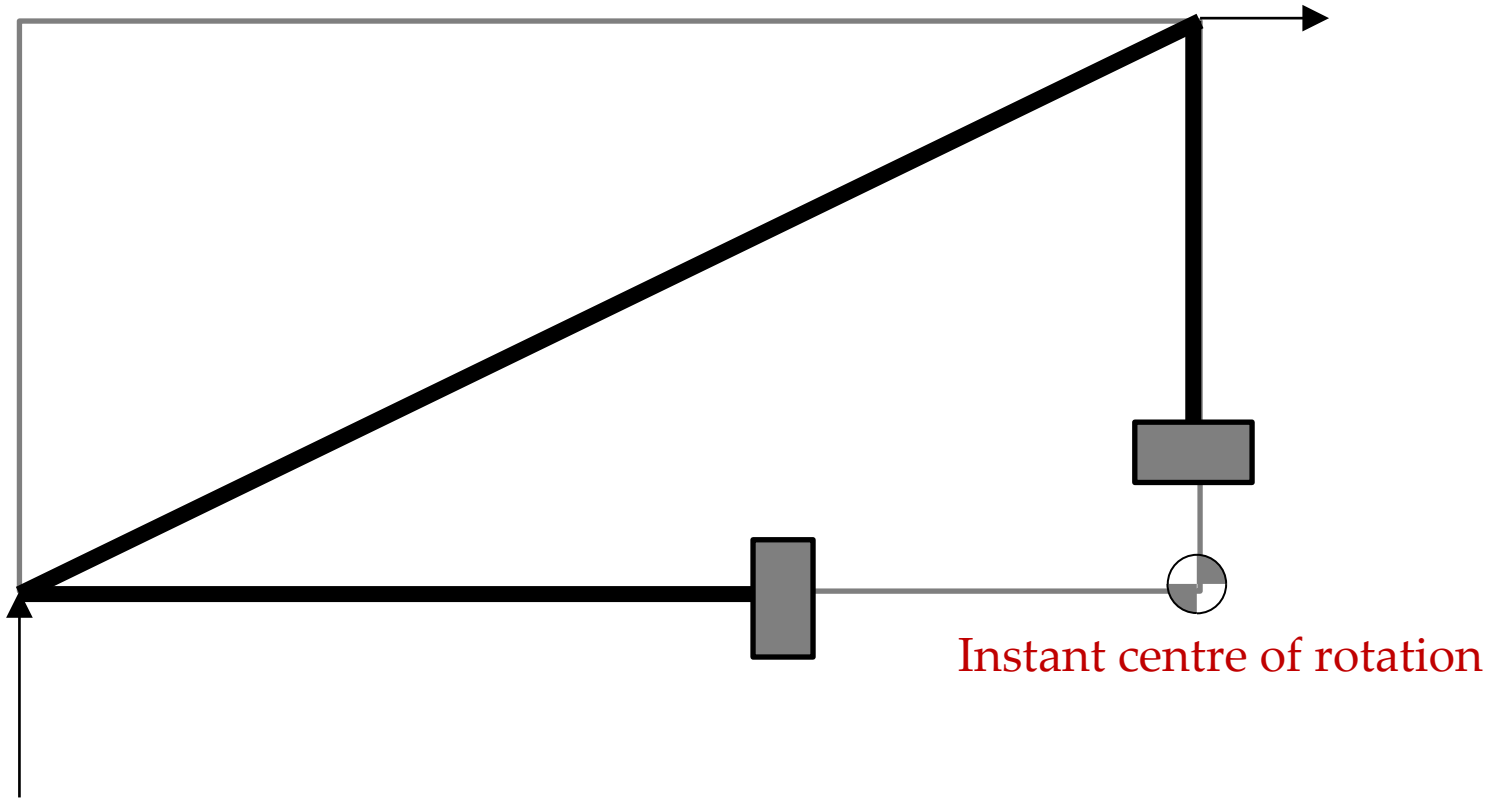
Instant centre of rotation



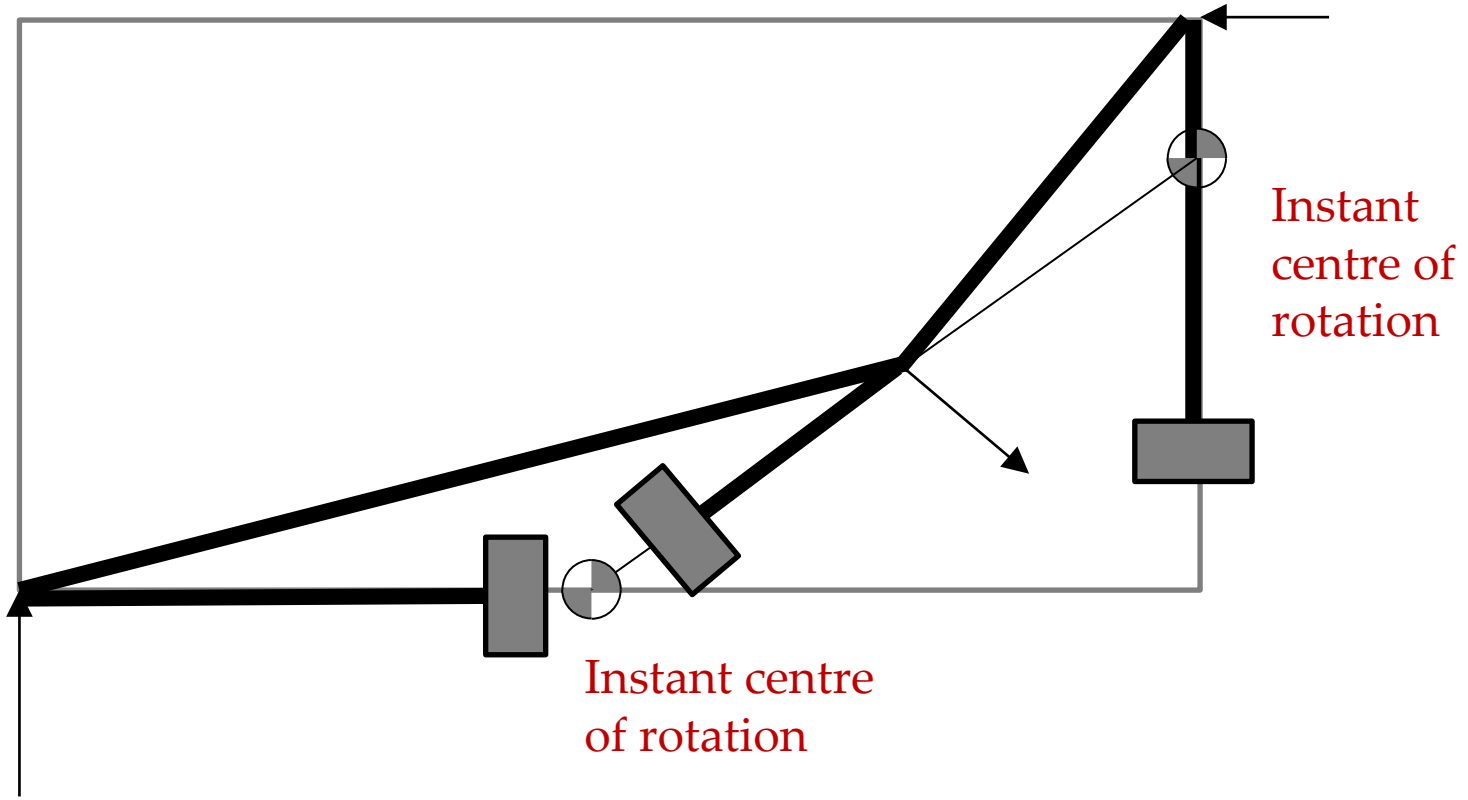
Q. Where is the fourth block?

A. It is the fixed frame!

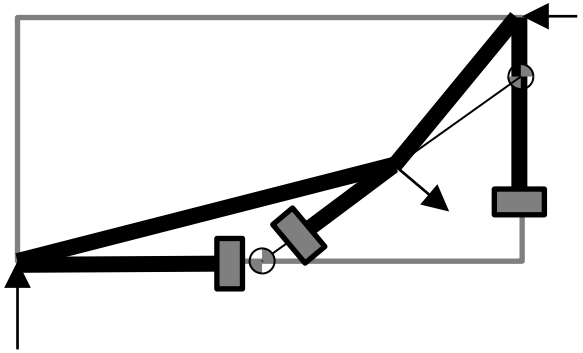
Instant centre method

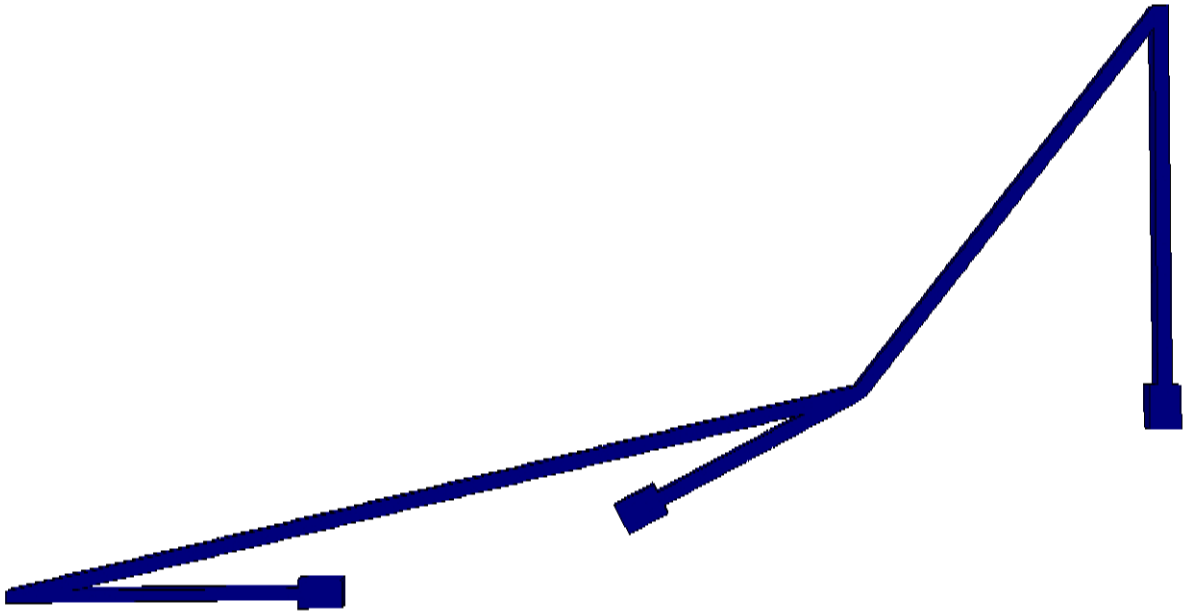


Instant centre method (non-intuitive specification)



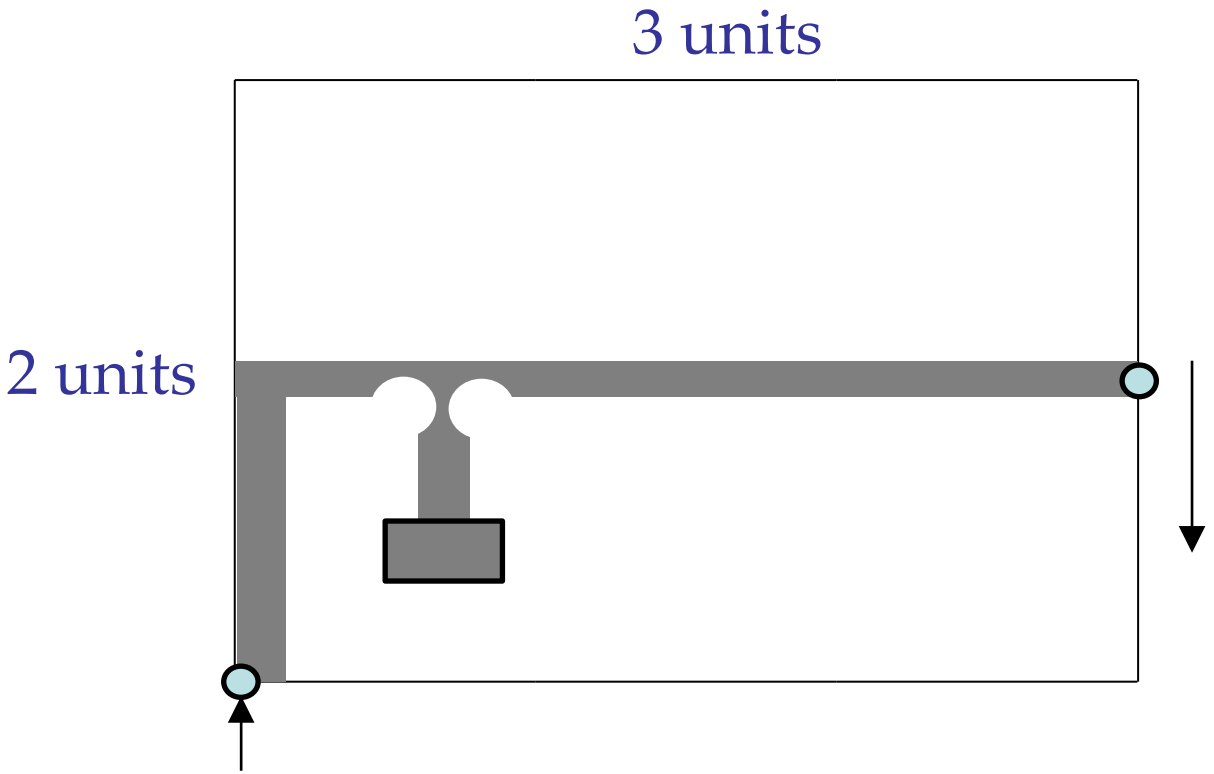
Validation with FEA





Quantitative specifications can also be dealt with.

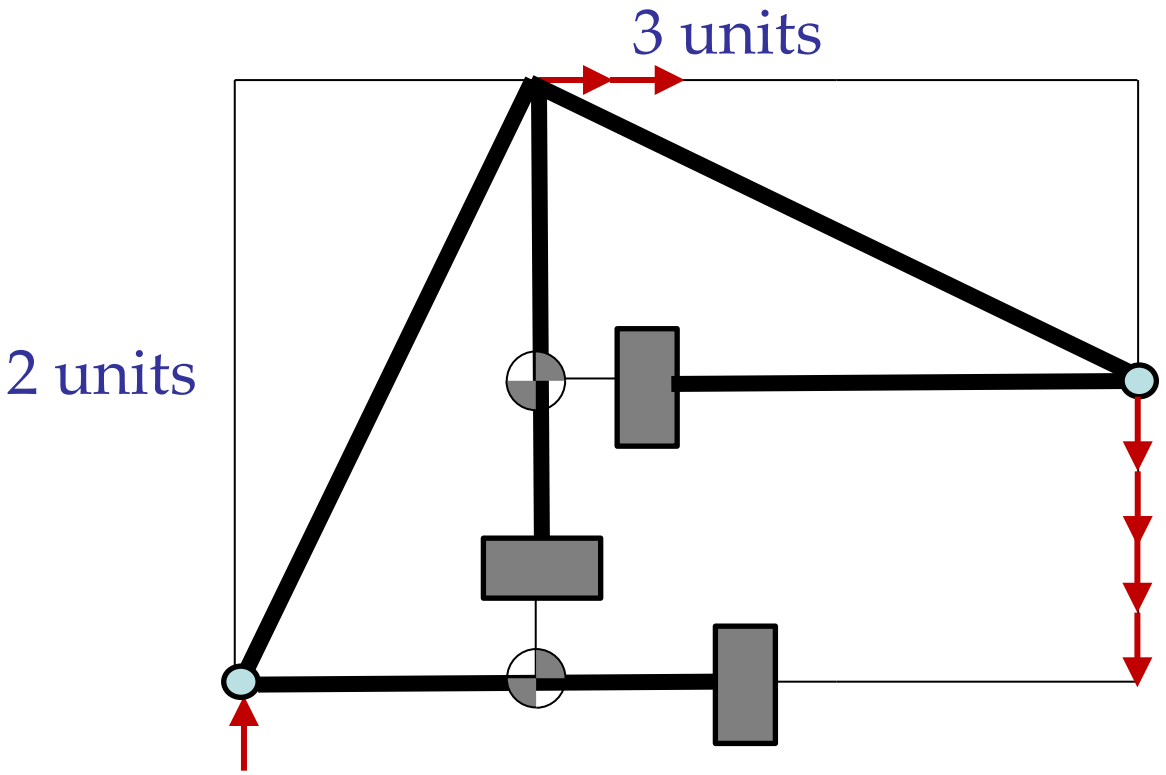
Want: Geometric Advantage, GA = 4



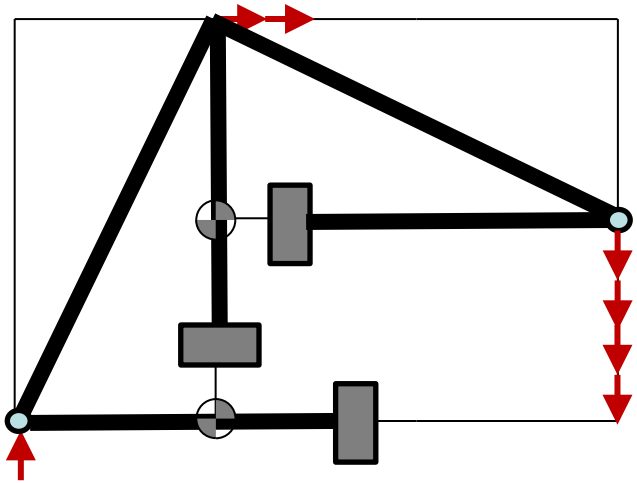
Will a simple lever work?

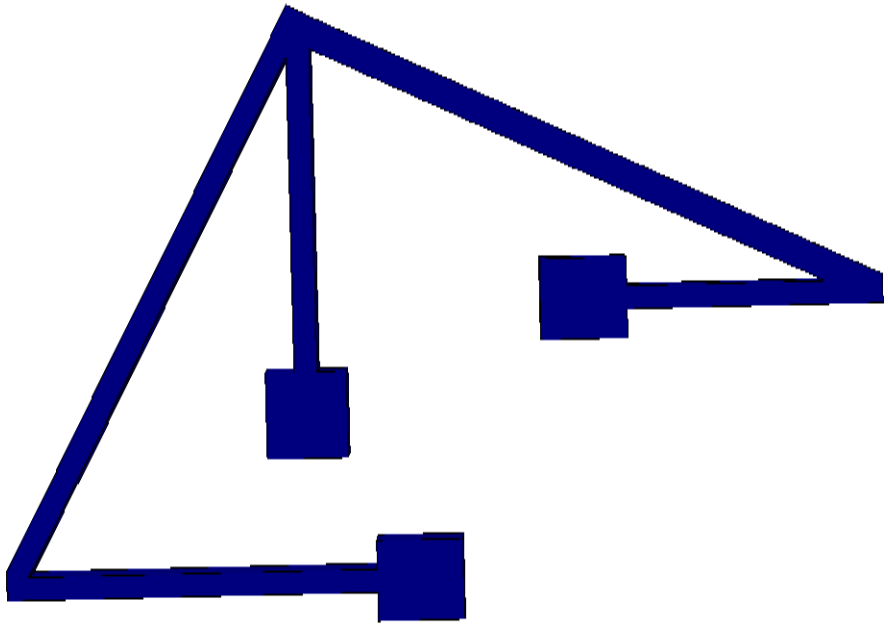
Quantitative specifications can also be dealt with.

Want: Geometric Advantage, GA = 4

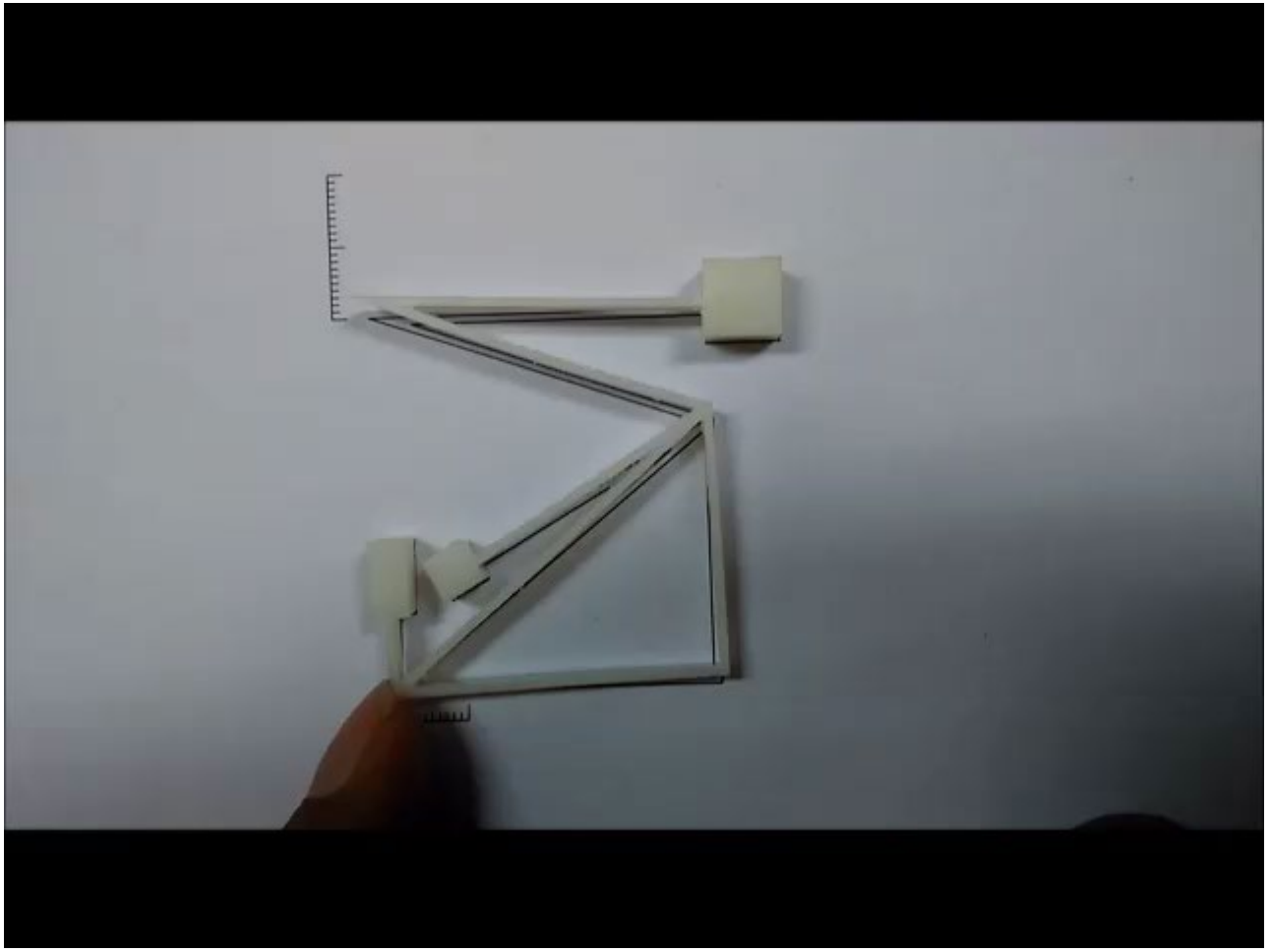


Validation with FEA



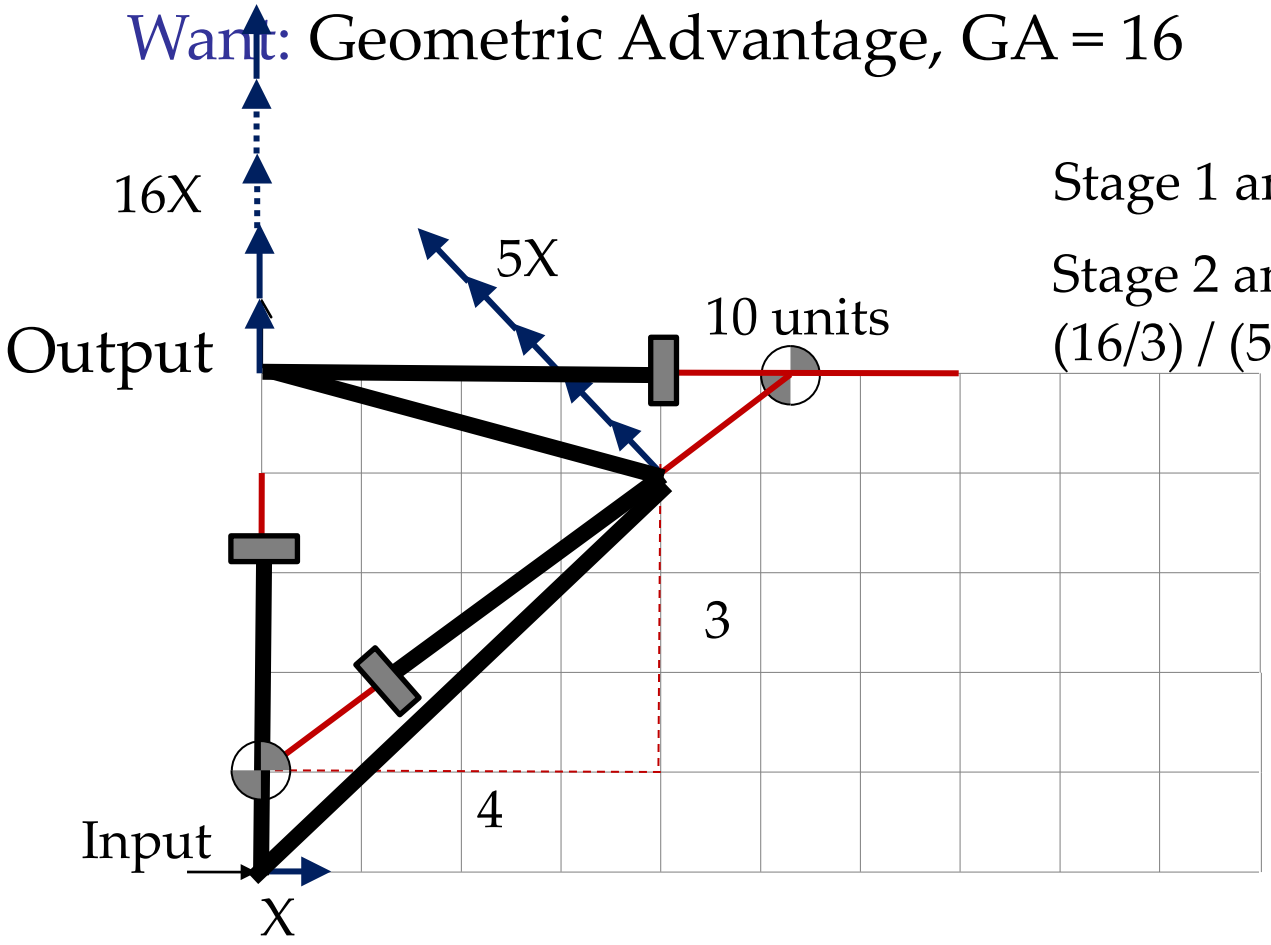


Design and 3D-print it!



An exercise for practice

Want: Geometric Advantage, GA = 16

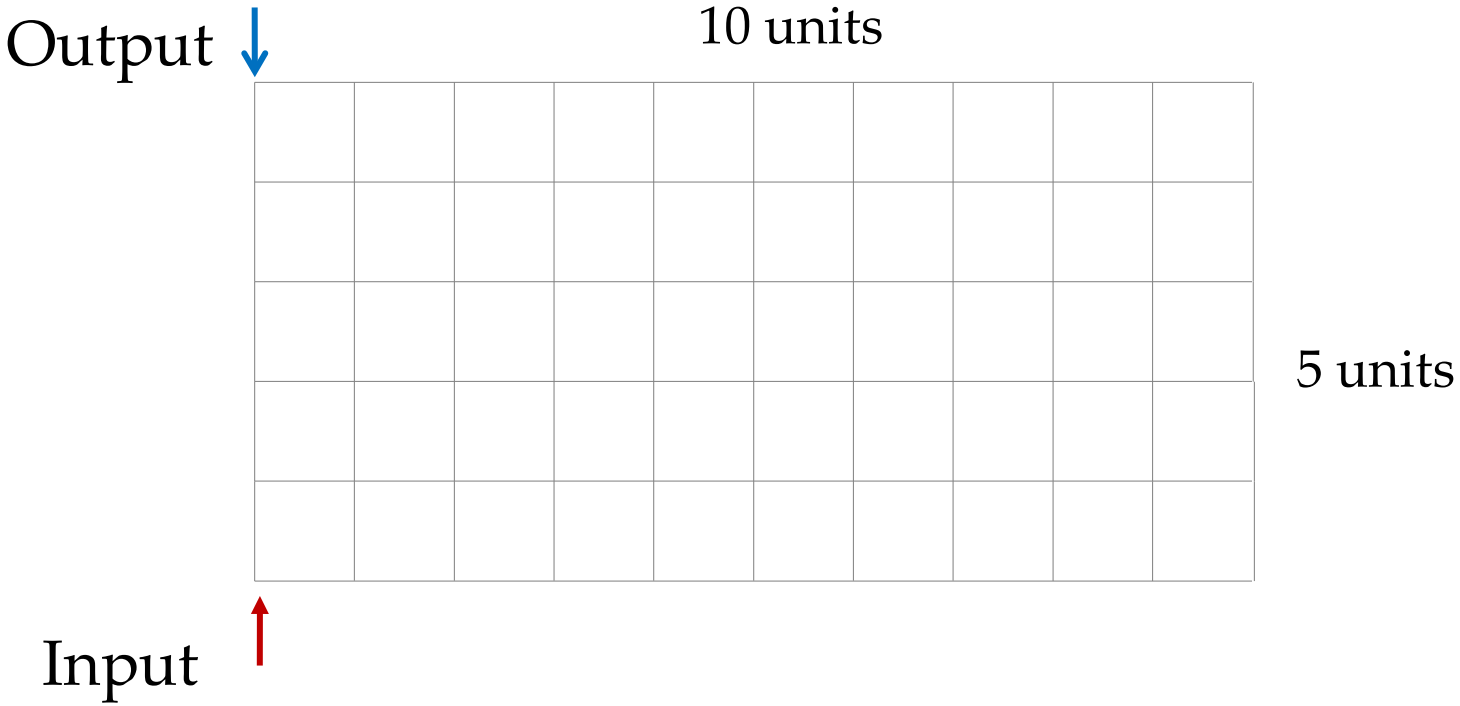


Stage 1 amplification = 5

Stage 2 amplification = (16/3) / (5/3) = 16/5

An exercise for you!

Want: as high a geometric advantage as possible.



Main points

- Instant centre concept applied to compliant mechanism design.
  - Instantaneous (linear) behavior is correct but not large-displacement (nonlinear) behavior.
  - Coupler body should be relatively stiff.
- A quick way to get a concept (topology) of a compliant mechanism.
- Could be a great initial guess for structural optimization-based approaches.
- An excellent tool for teaching and brain-storming.

Further reading

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