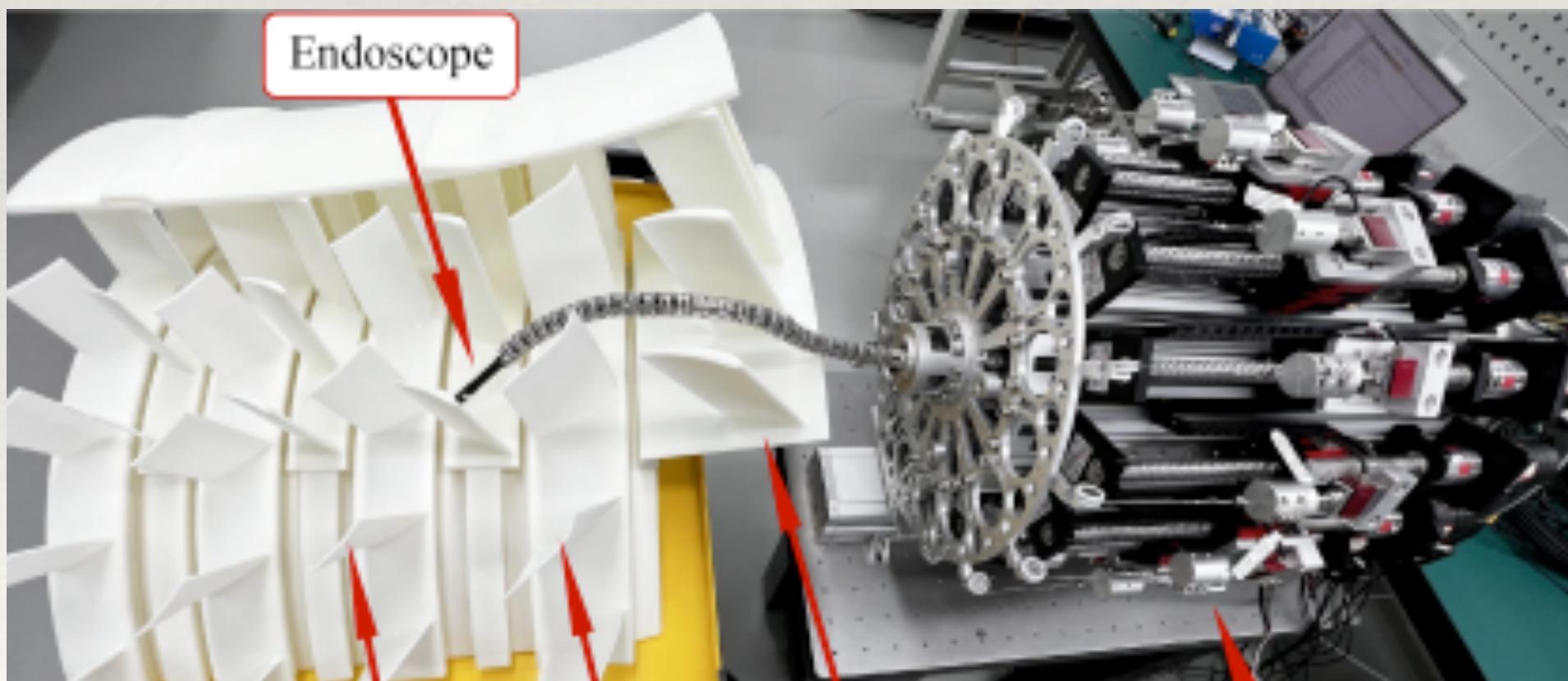
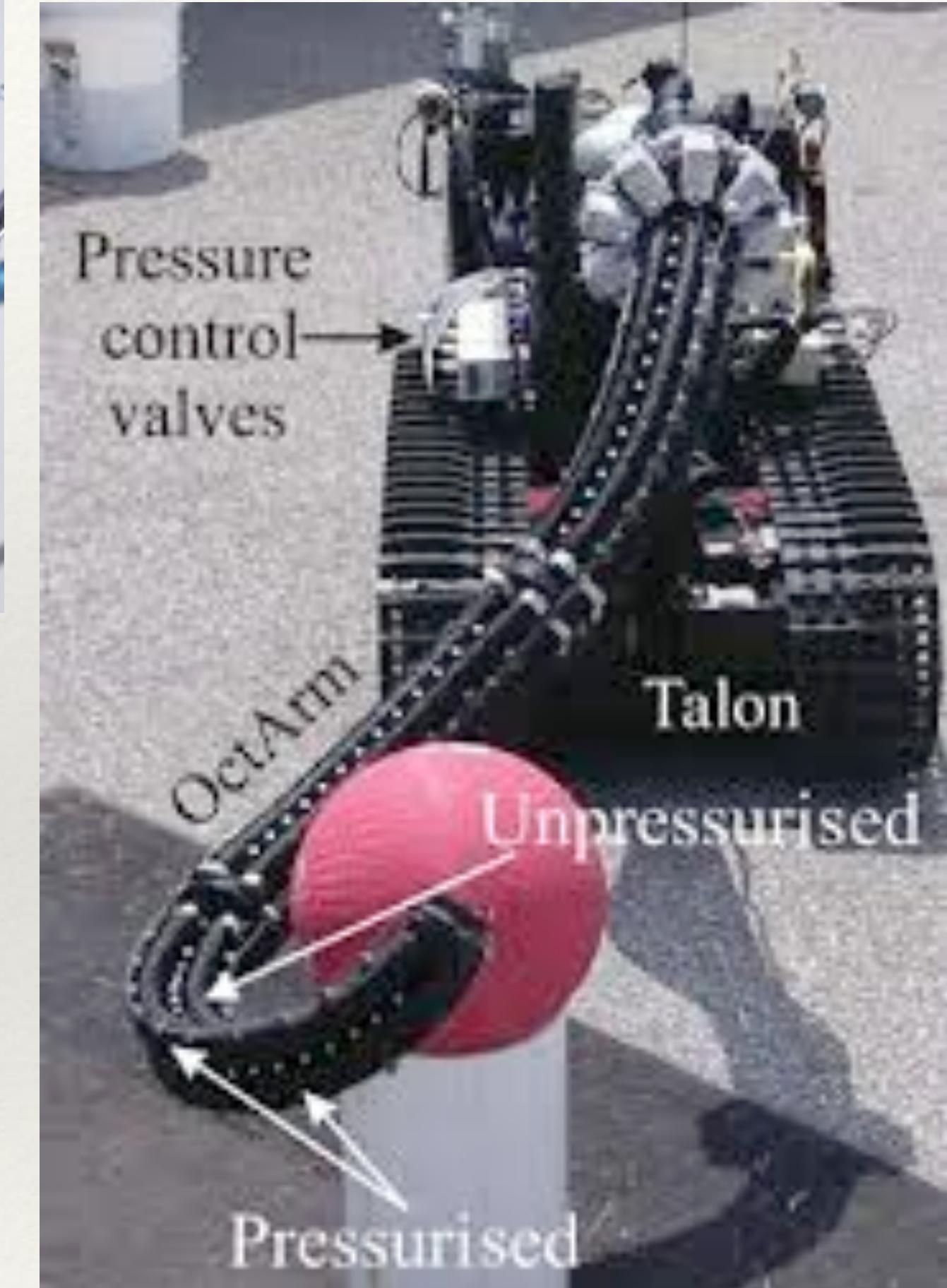
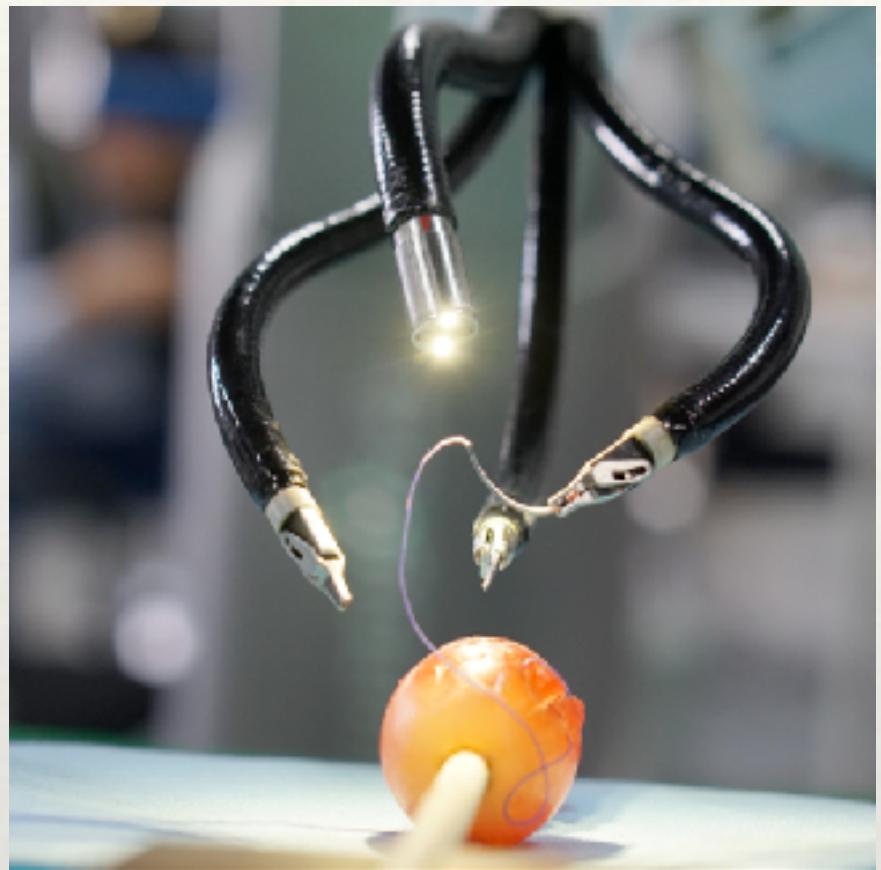


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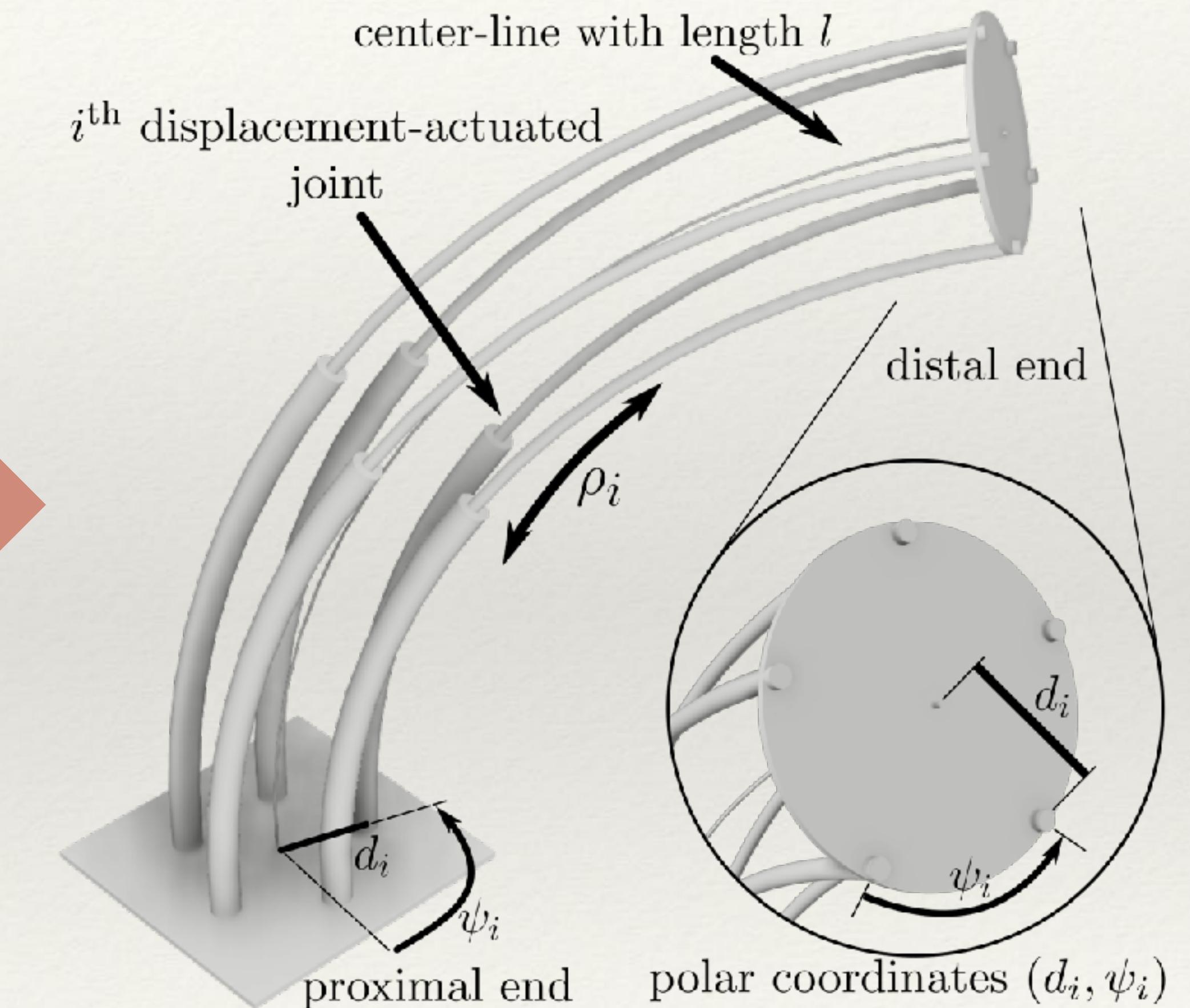
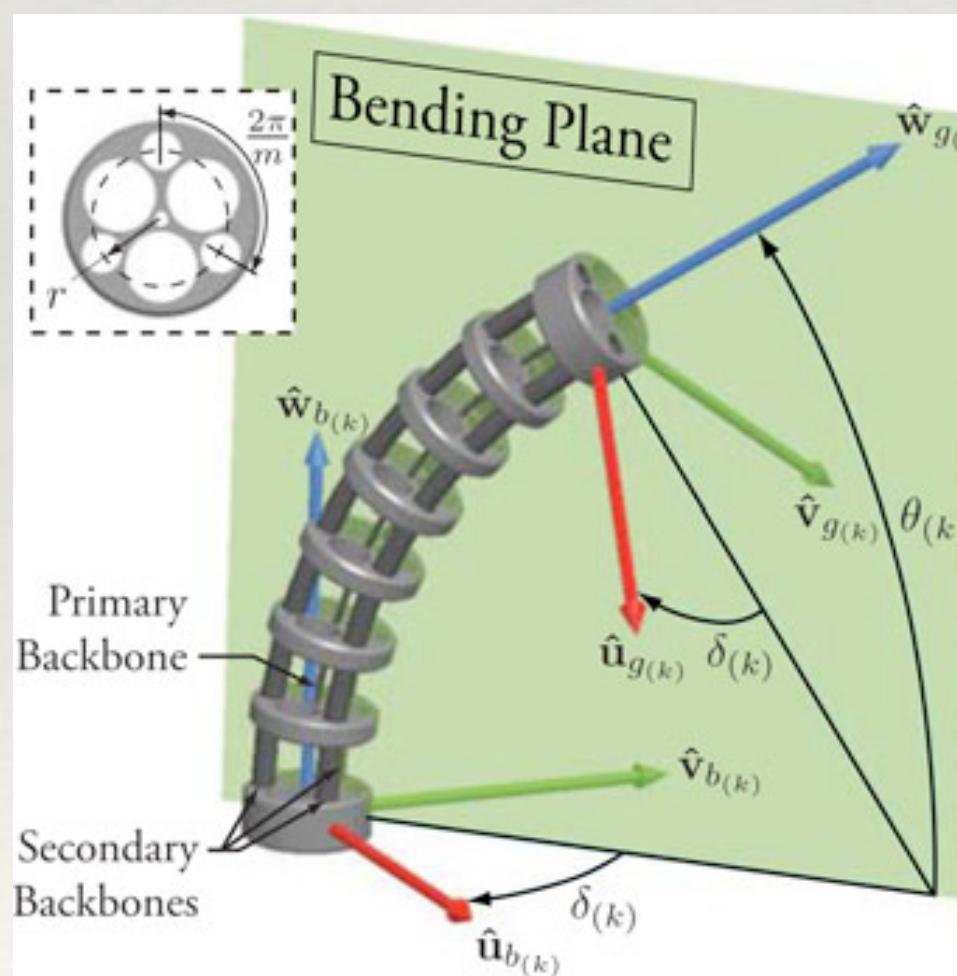
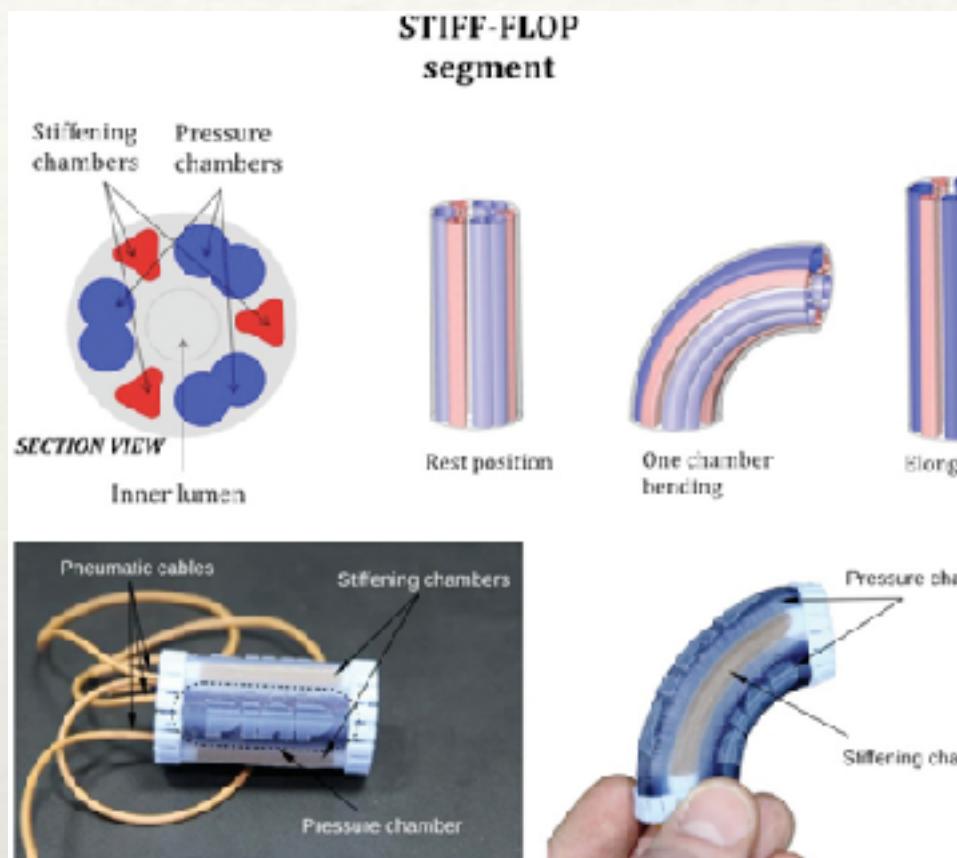
Clarke Transform and Encoder-Decoder Architecture for Arbitrary Joint Locations in Displacement-Actuated Continuum Robots

Reinhard M. Grassmann
Jessica Burgner-Kahrs

Observation



Displacement-Actuated Continuum Robot



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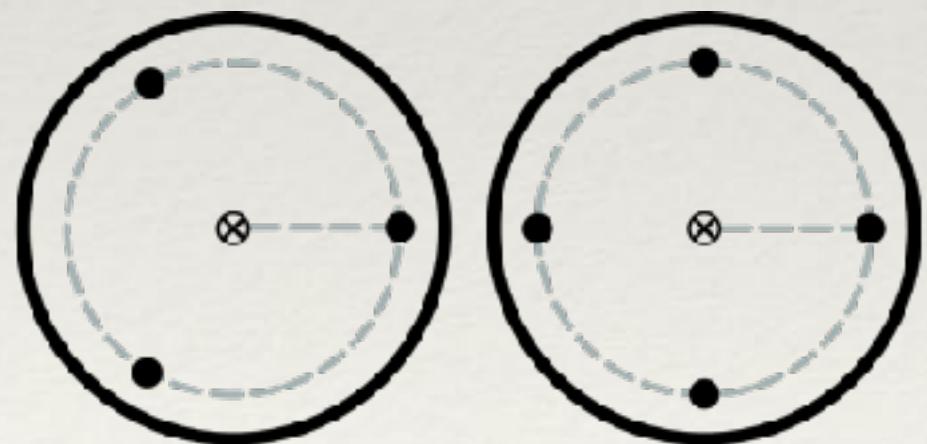
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Joint Location

joint location



limited option



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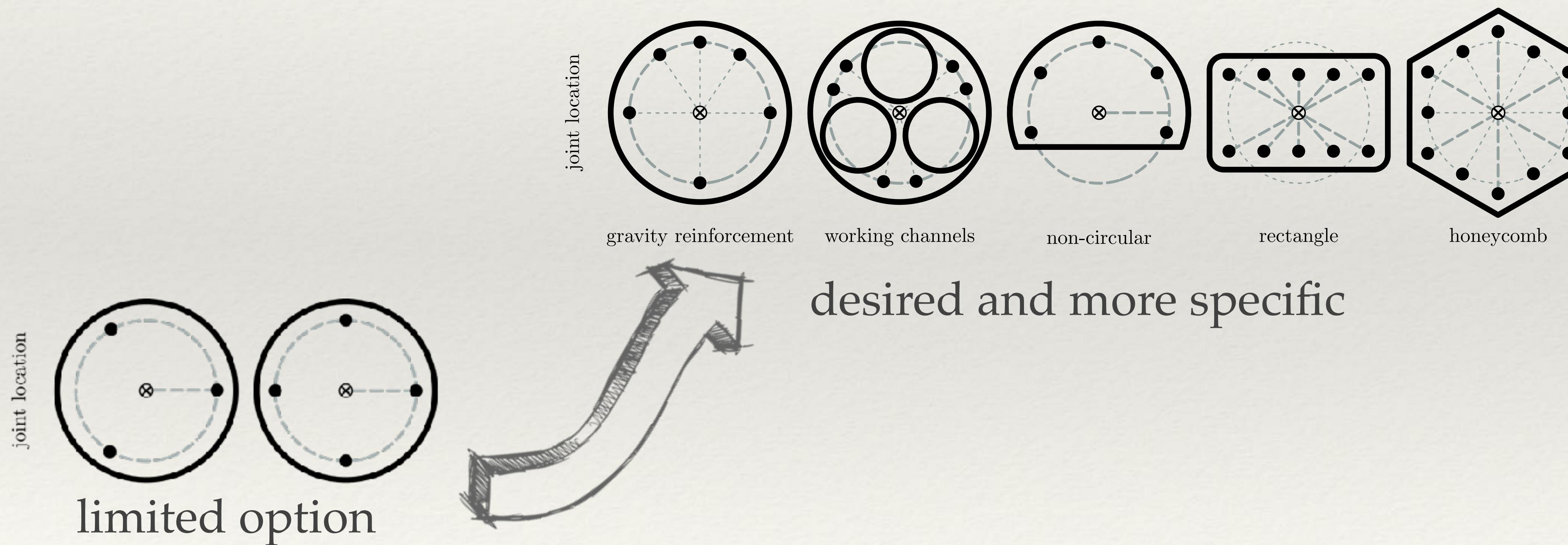


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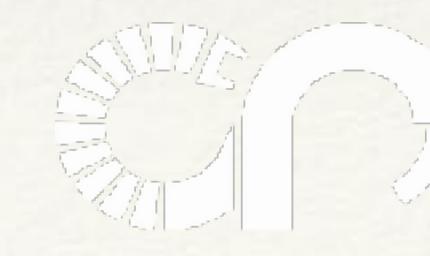
Joint Location



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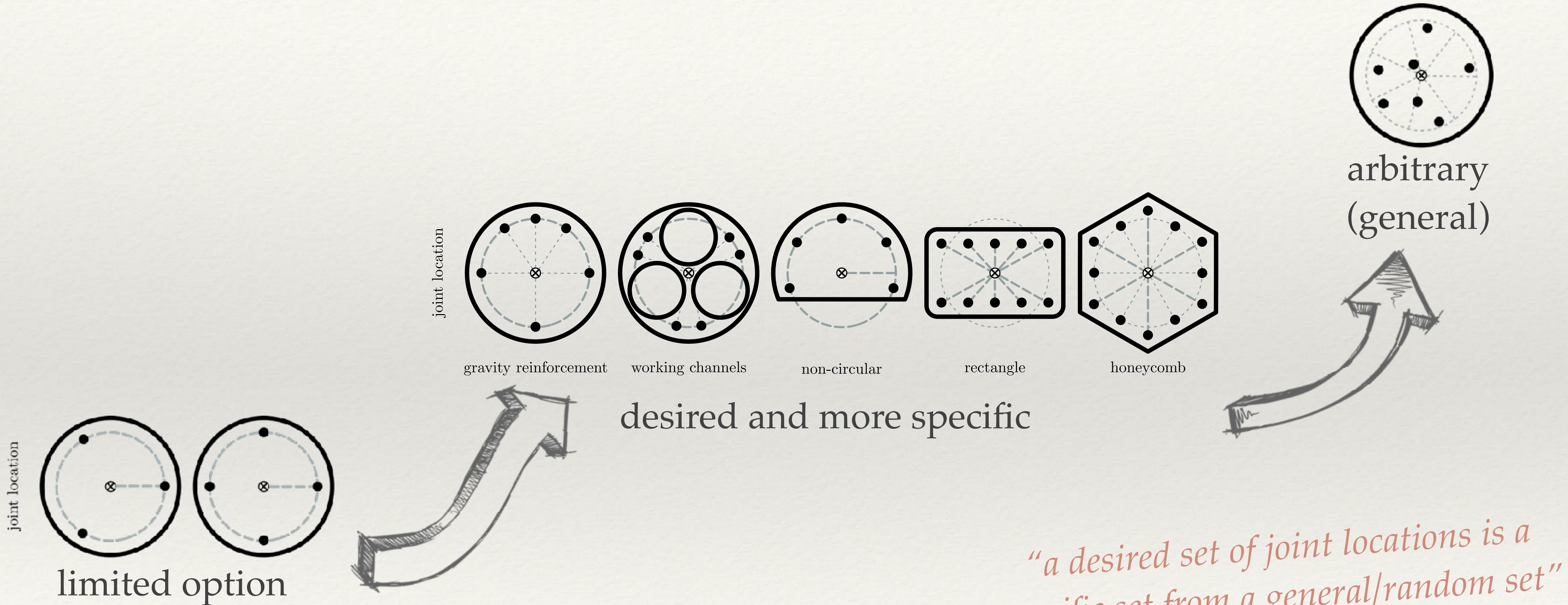


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Joint Location



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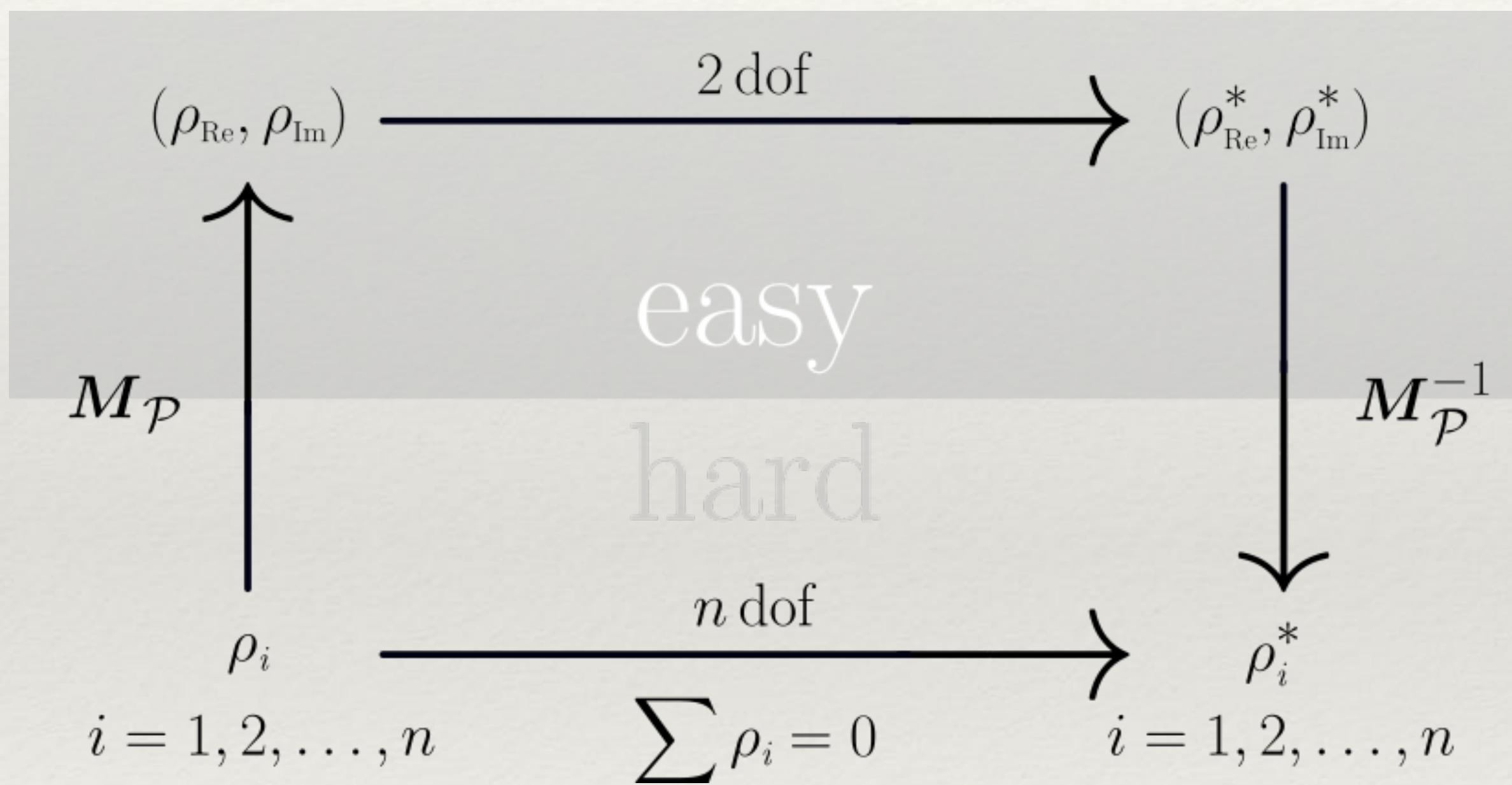
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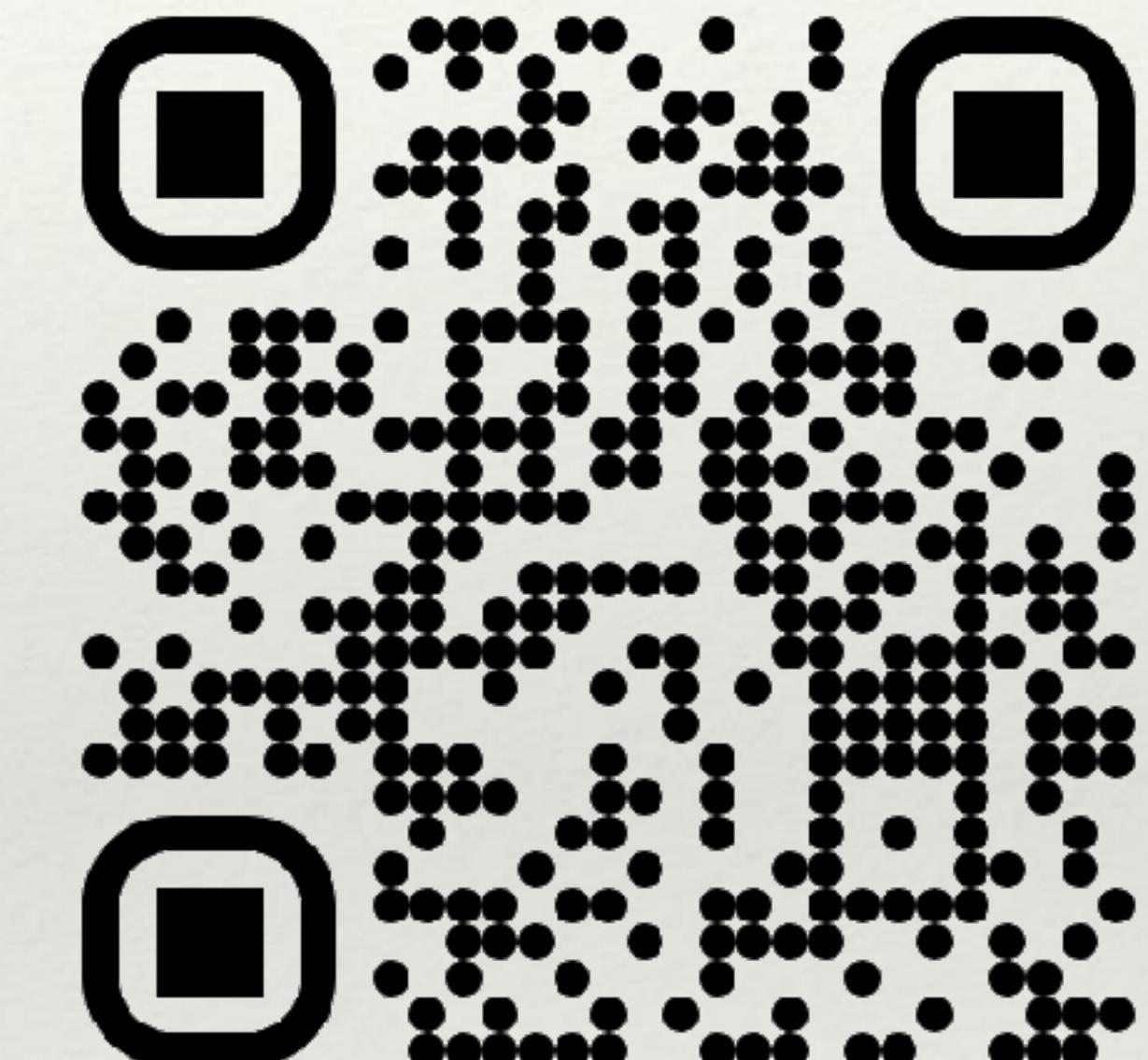
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Clarke Transform In a Nutshell

“Similar to Laplace Transform”

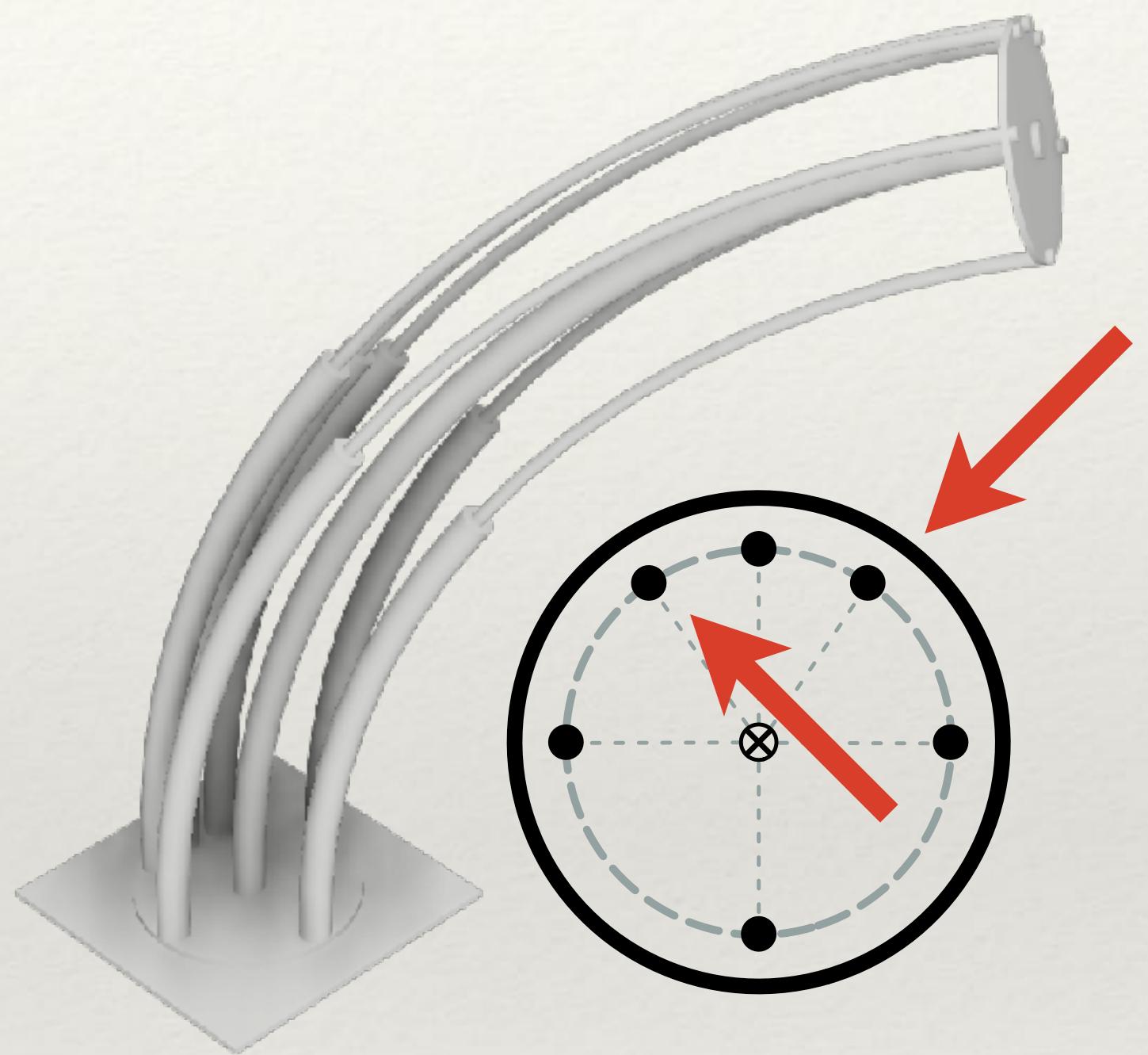
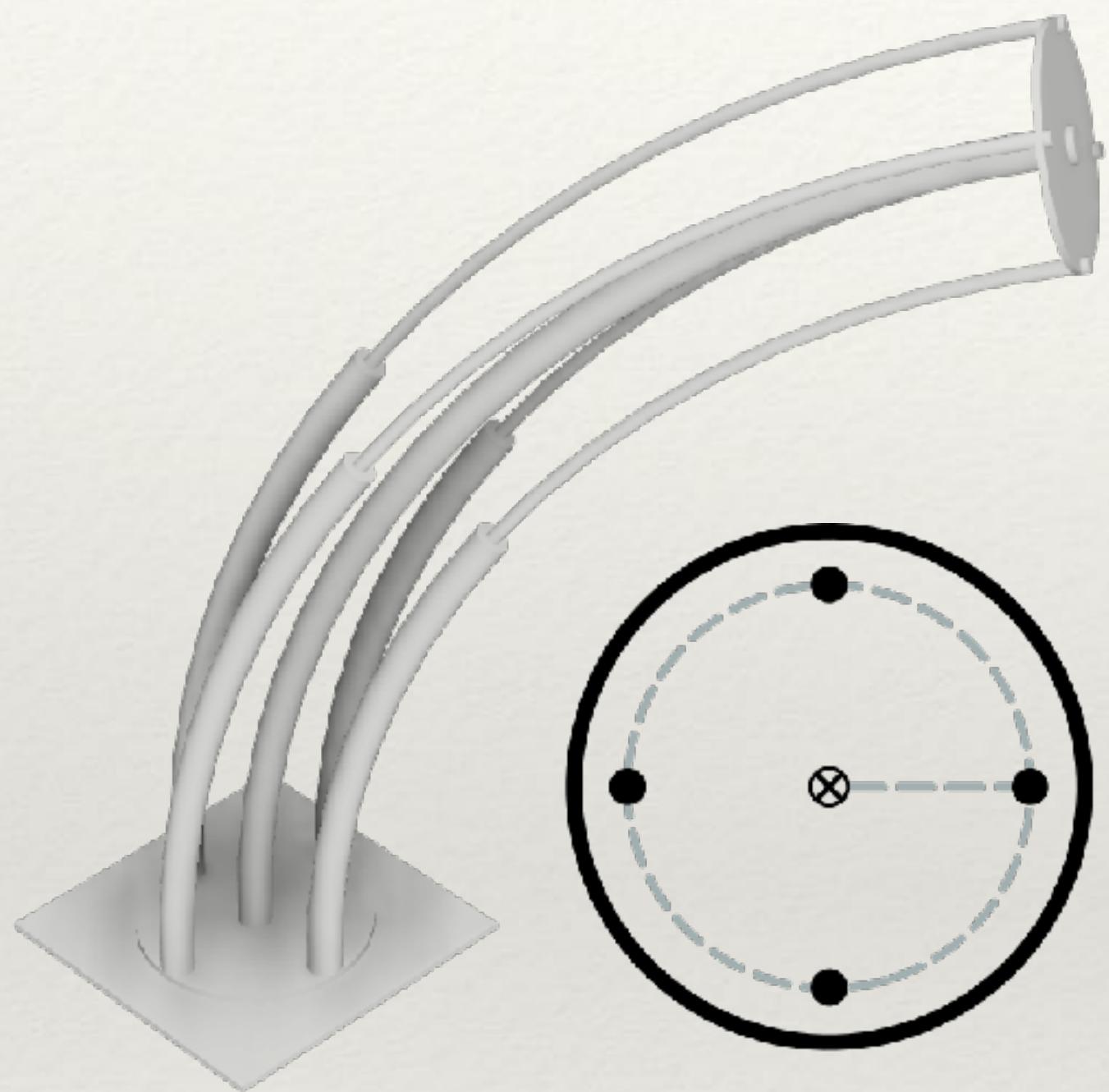


Clarke transform and Clarke coordinates

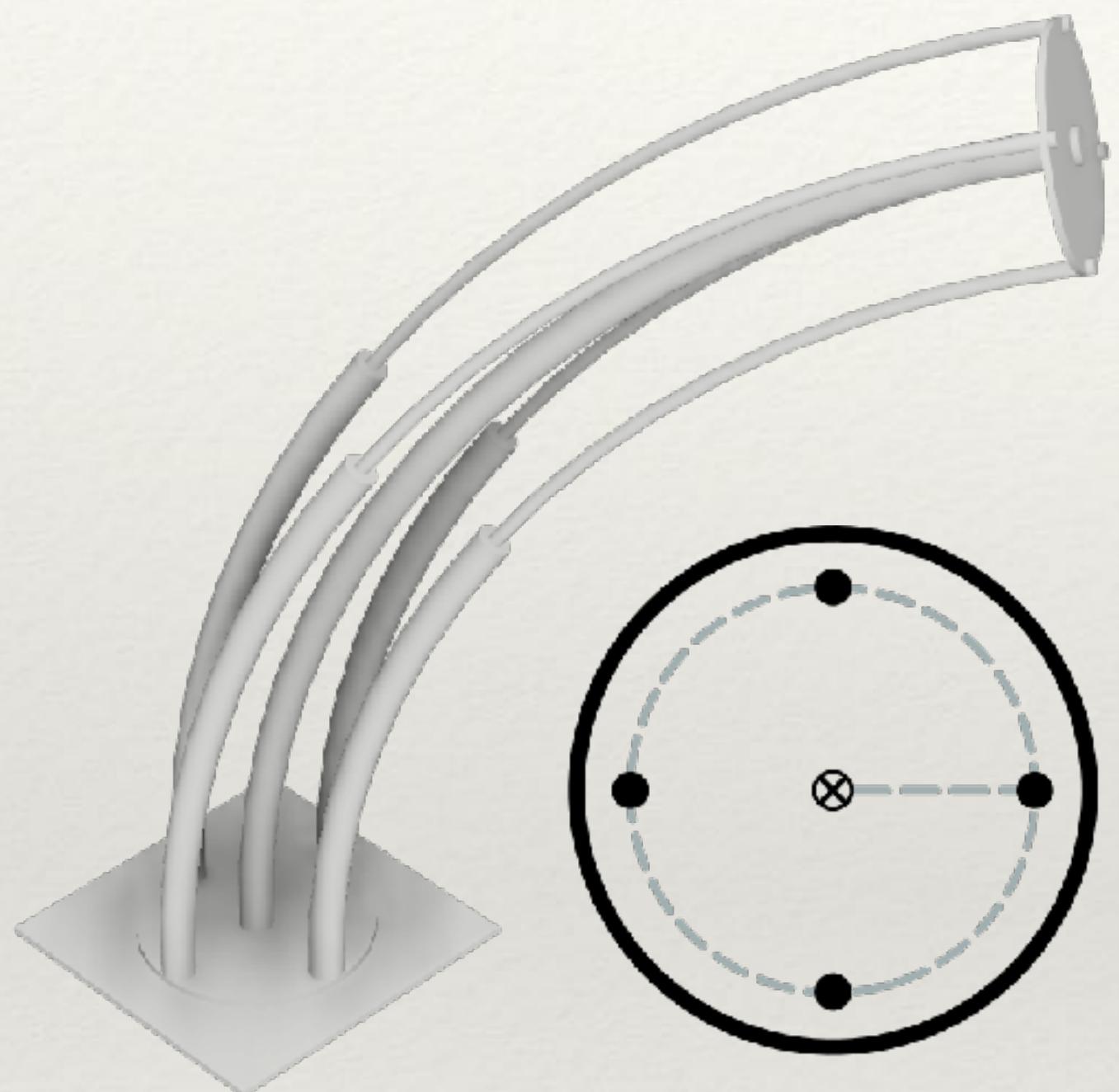


Clarke Transform
(manuscript on arXiv)

Encoder-Decoder Architecture



Encoder-Decoder Architecture



surrogate robot
(robot A)

$$\begin{bmatrix} \rho_1 \\ \rho_2 \\ \vdots \\ \rho_n \end{bmatrix} \subset \mathbb{R}^n$$

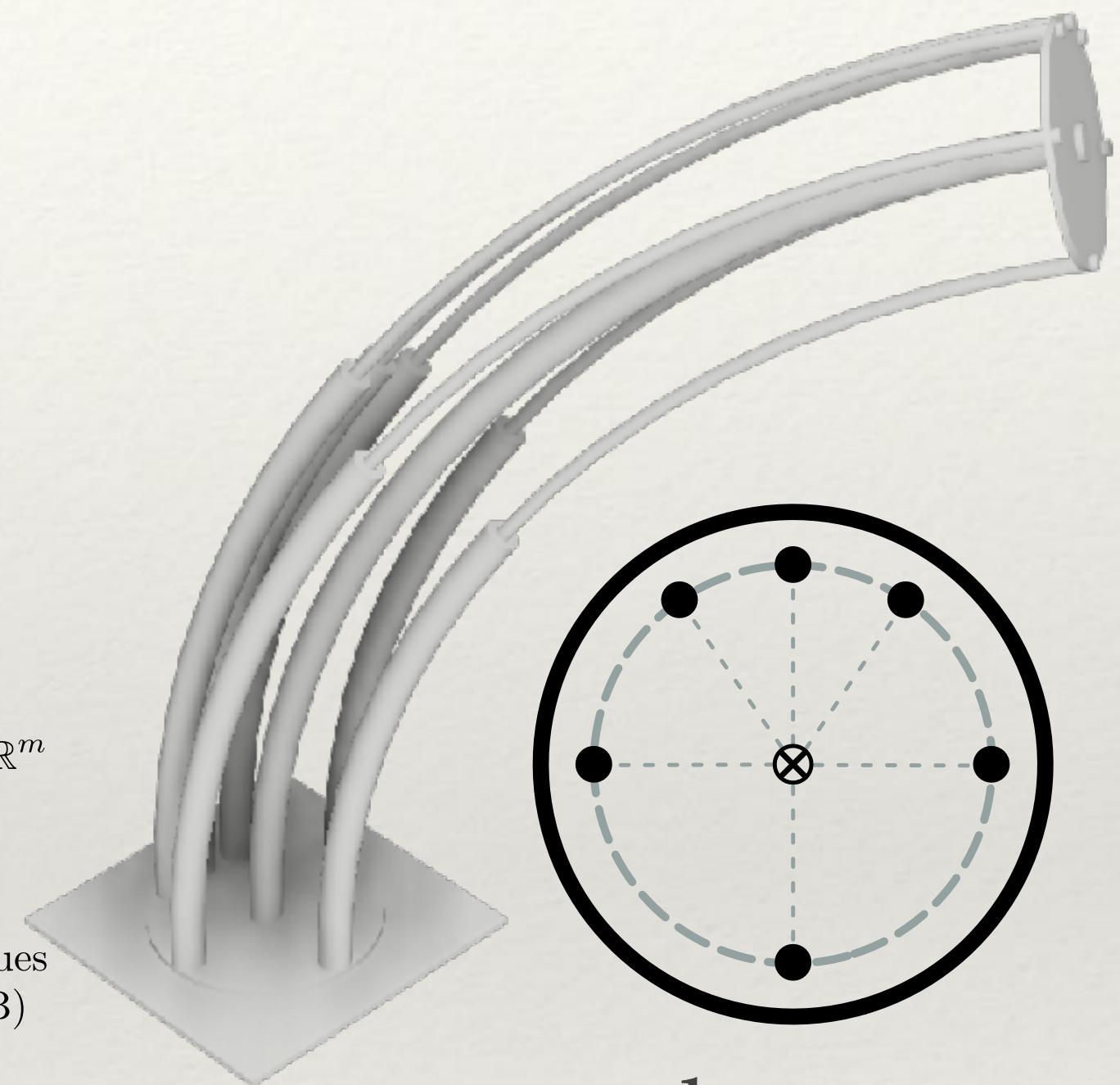
Joint values
(robot A)

*“Boundary condition:
Don’t reinvent the wheel”*



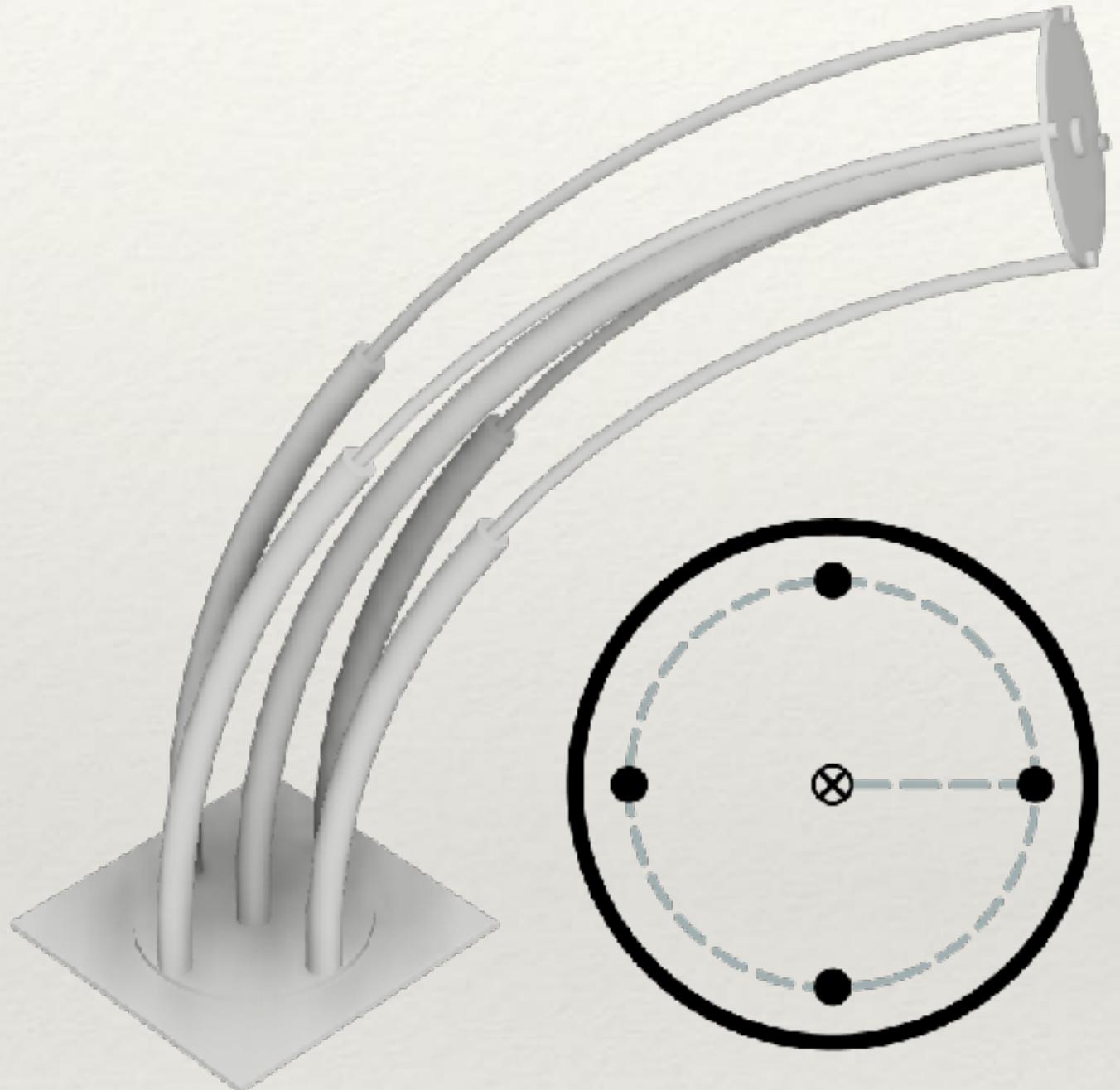
$$\begin{bmatrix} \rho_1 \\ \rho_2 \\ \vdots \\ \rho_m \end{bmatrix} \subset \mathbb{R}^m$$

Joint values
(robot B)

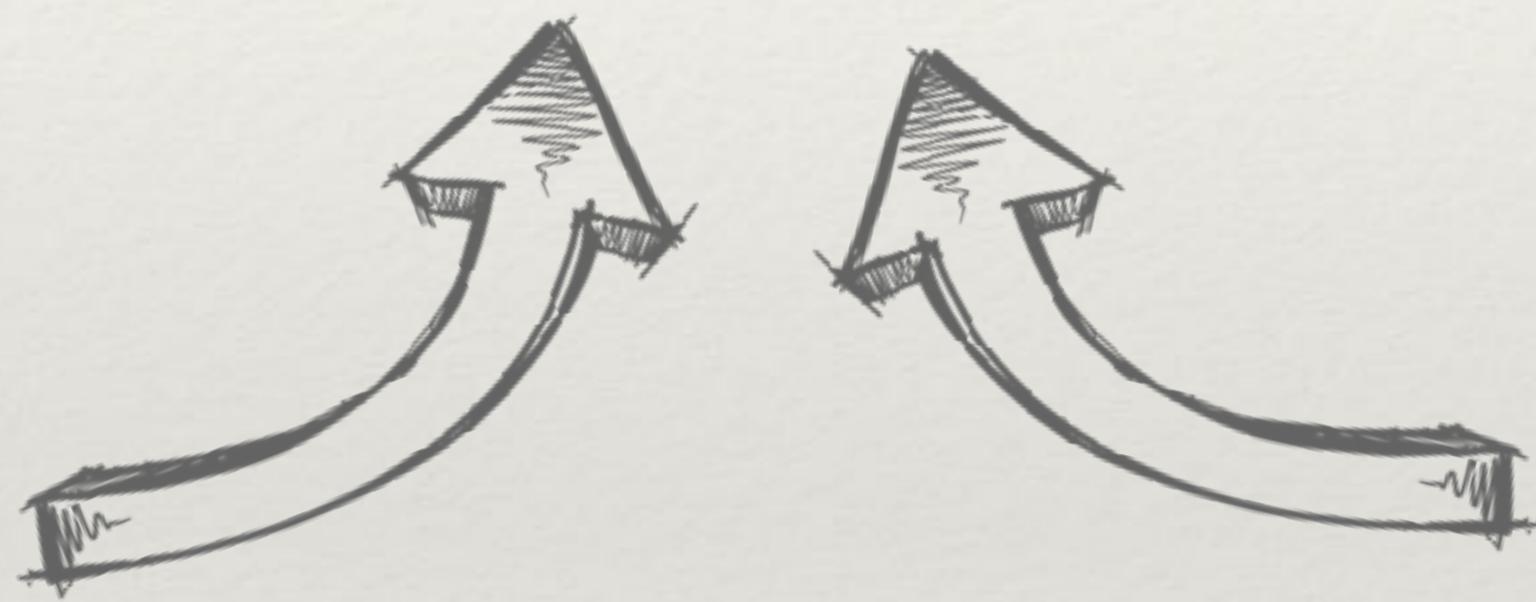
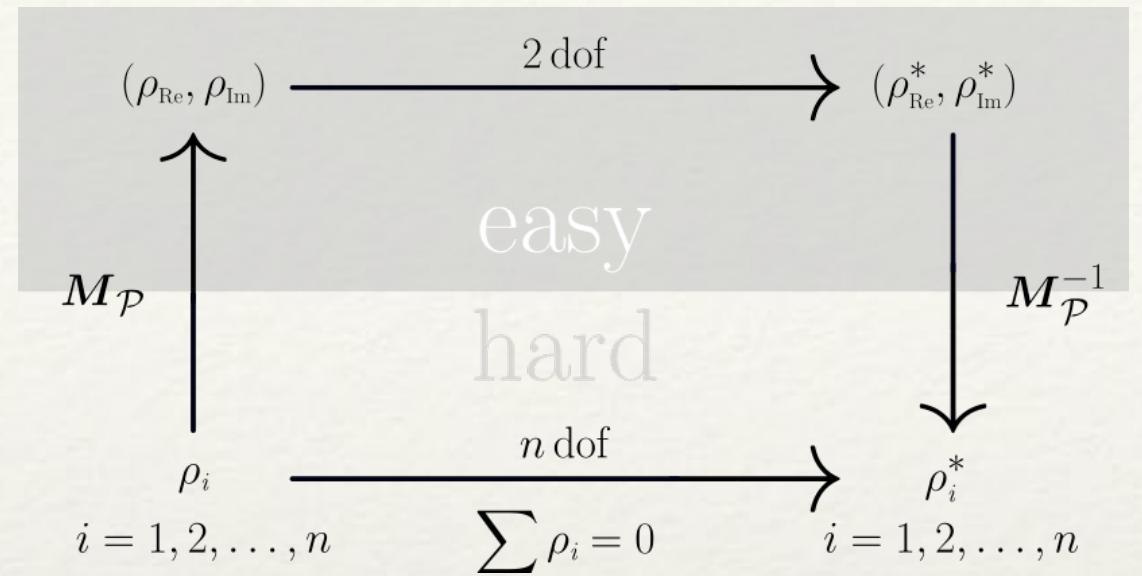


target robot
(robot B)

Encoder-Decoder Architecture

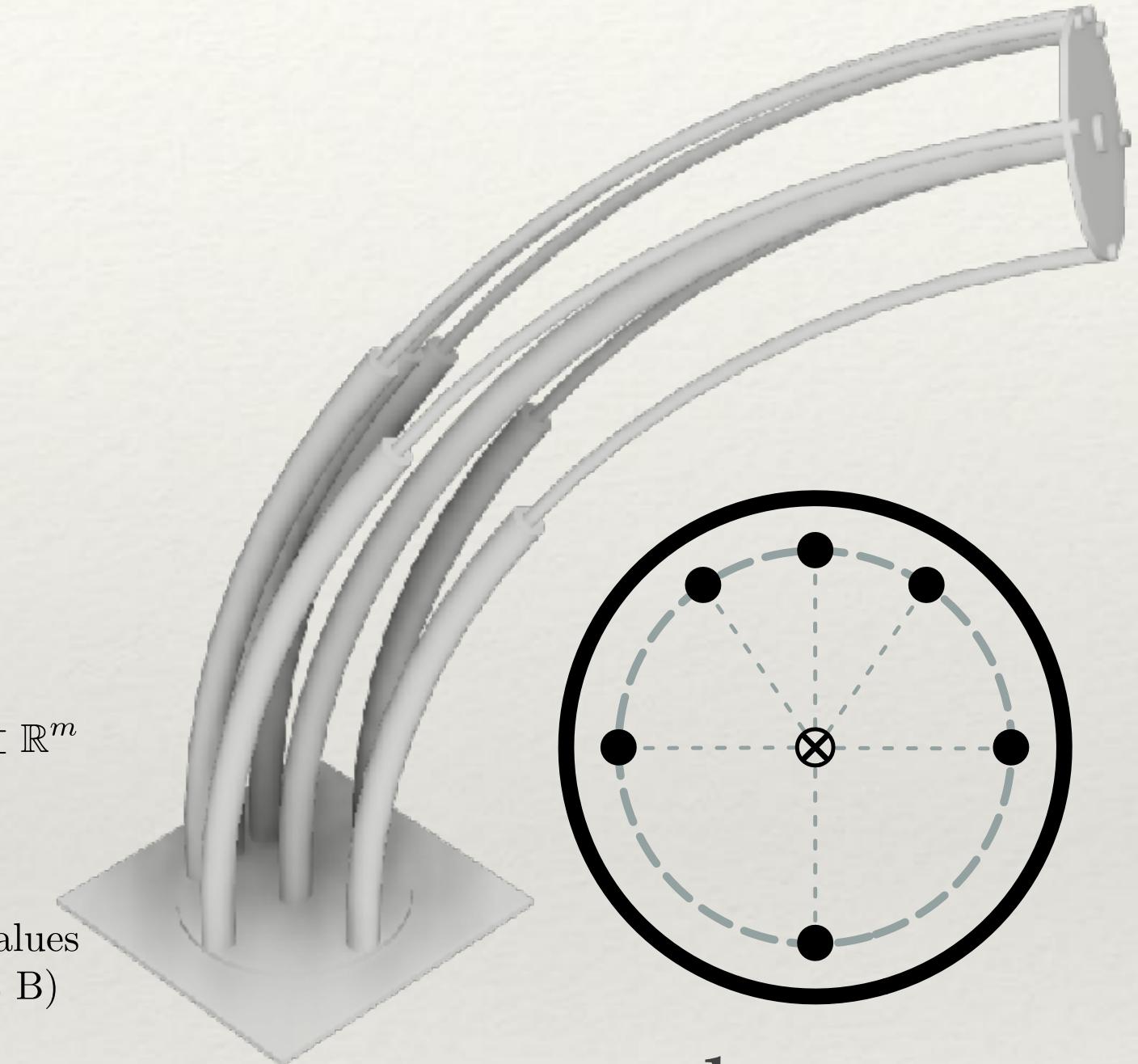


surrogate robot
(robot A)



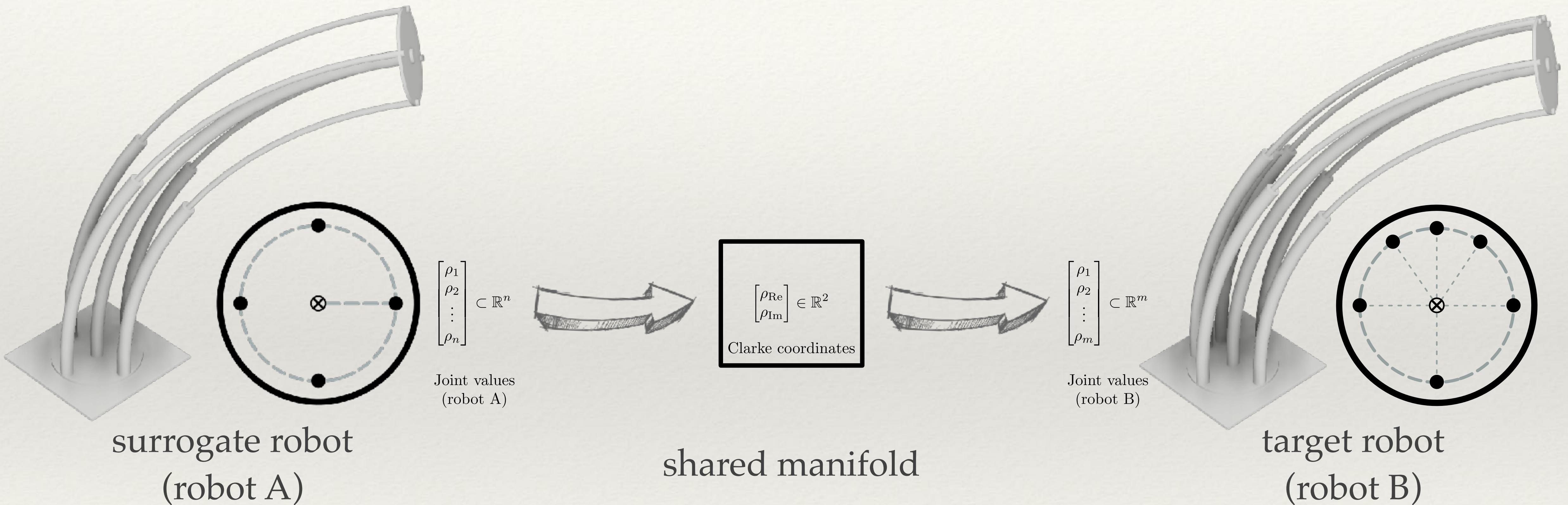
$$\begin{bmatrix} \rho_1 \\ \rho_2 \\ \vdots \\ \rho_m \end{bmatrix} \subset \mathbb{R}^m$$

Joint values
(robot B)

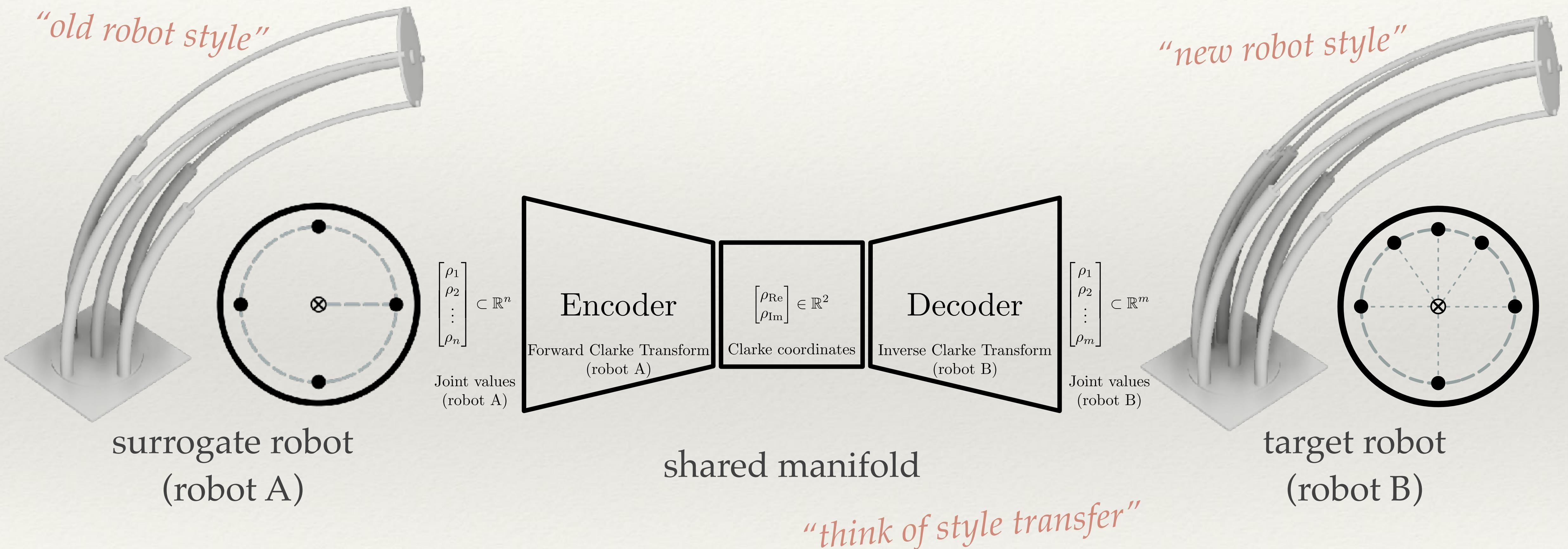


target robot
(robot B)

Encoder-Decoder Architecture



Encoder-Decoder Architecture



Closed-Form, Compact, and Interpretable

$$\rho_{(\text{robot B})} = \overbrace{l_{(\text{robot B})} \text{diag} (d_{i,(\text{robot B})}) M_{\mathcal{P}(\text{robot B})}^{-1}}^{\text{adds design parameters of robot B}} \cdot \underbrace{\frac{1}{l_{(\text{robot A})}} M_{\mathcal{P}(\text{robot A})} \text{diag} \left(\frac{1}{d_{i,(\text{robot A})}} \right)}_{\text{removes design parameters of robot A}} \rho_{(\text{robot A})}$$

The diagram illustrates the transformation of robot shapes through a series of icons. It starts with a circular robot labeled 'gravity reinforcement' with a central joint location marked by a cross. An arrow points to a more complex circular robot labeled 'working channels'. This is followed by a 'non-circular' robot with irregular boundaries and internal features. Next is a 'rectangle' robot. Then a 'honeycomb' robot. Finally, an arrow points back to a circular robot, indicating the removal of design parameters of robot A.

joint location

gravity reinforcement

working channels

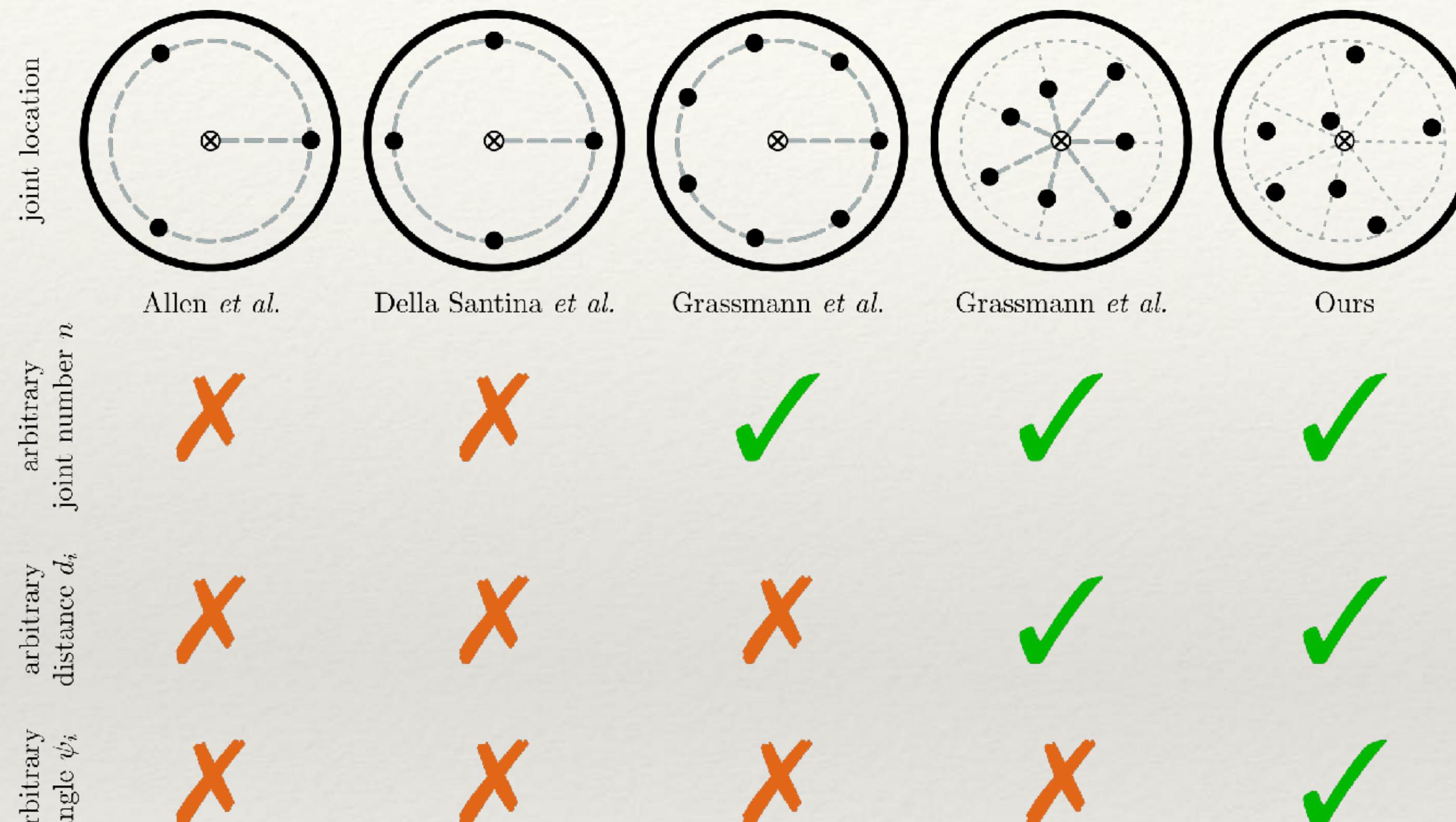
non-circular

rectangle

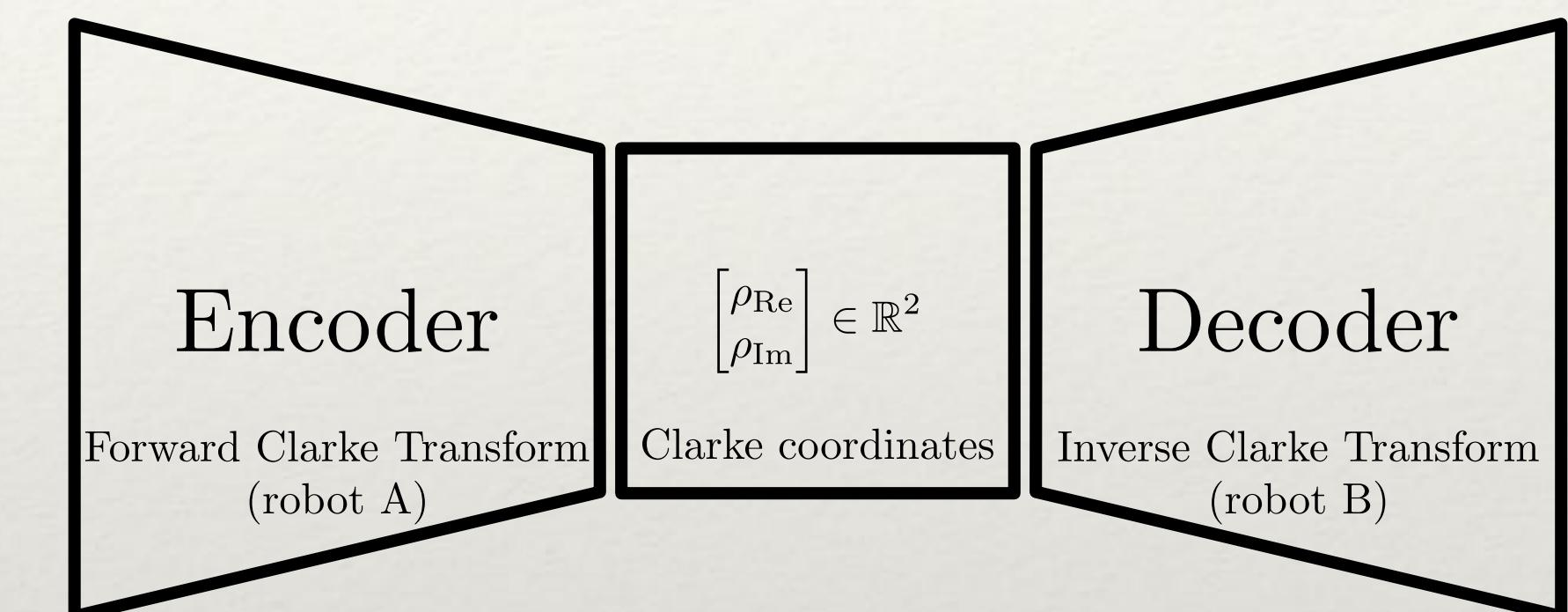
honeycomb

joint location

Contribution



arbitrary joint locations for desired joint locations

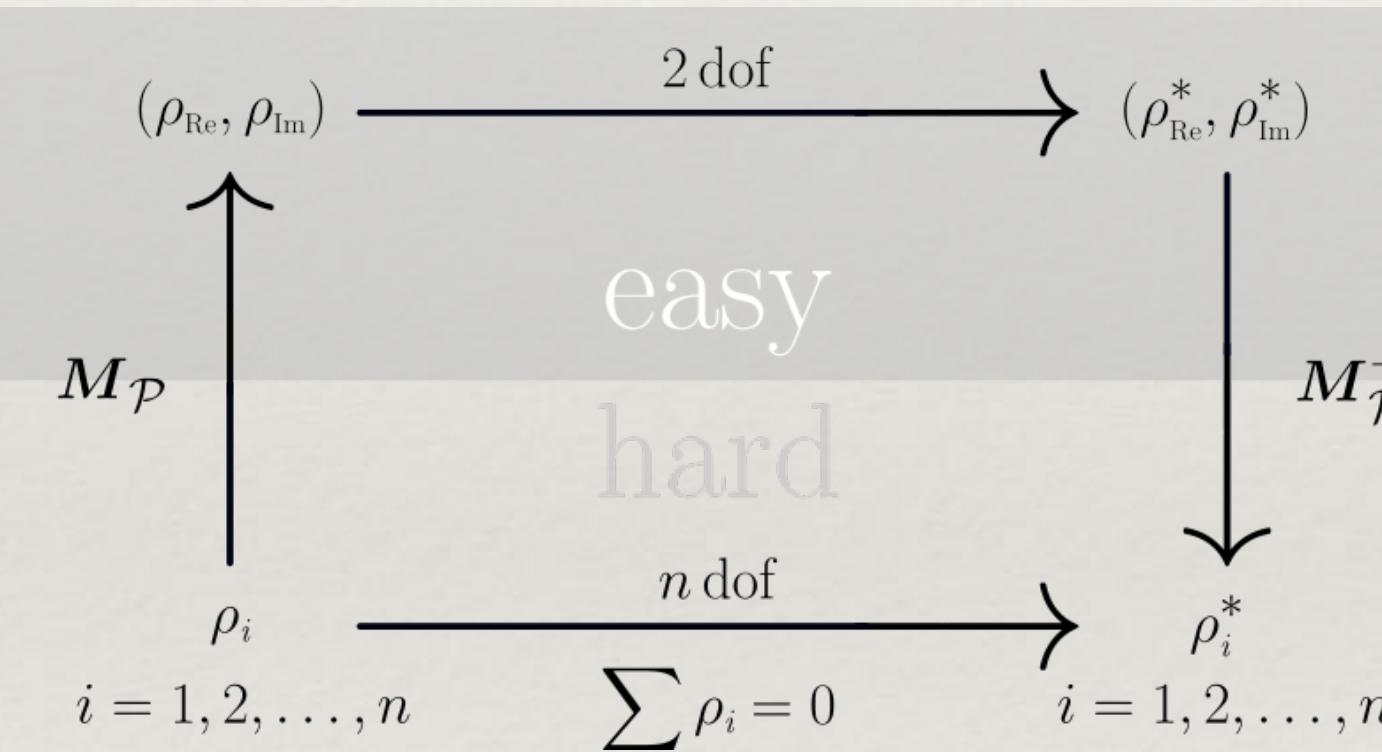


method for re-using previous methods

Thank you for your time and attention



Paper ID 22



Call for Action:
Use Clarke Transform



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Going beyond the limitations of three and four joints per segments. Customize the joint location to your needs and reuse all previous methods.

Session AA-4 joint location gravity reinforcement working channels non-circular rectangle honeycomb Paper ID 22

Clarke Transform and Encoder-Decoder Architecture for Arbitrary Joints Locations in Displacement-Actuated Continuum Robots
Reinhard M. Grassmann & Jessica Burgner-Kahrs

Motivation

- current joint configuration
 - limited to $n = 3$ and $n = 5$
 - symmetric
- desired joint configuration
 - task specific

Approach

- use Clarke Transform
- exploit shared 2-dof manifold
 - Clarke coordinates
 - map onto manifold, map back to joint space
 - encoder-decoder architecture

Results

- arbitrary joint location
 - from any to specific
- form surrogate robot to specific robot
- solution is linear and exact

$$\rho_{(\text{robot B})} = \underbrace{l_{(\text{robot B})} \text{diag}(d_{i,(\text{robot B})})}_{\text{adds design parameters of robot B}} \cdot \underbrace{\frac{1}{l_{(\text{robot A})}} M_P^{-1}(\text{robot A}) \text{diag}\left(\frac{1}{d_{i,(\text{robot A})}}\right)}_{\text{removes design parameters of robot A}} \rho_{(\text{robot A})}$$

Conclusion

- overcome limitation
- new possibilities
 - algorithmic
 - mechanical design

displacement-actuated continuum robot

Clarke Transform and Clarke coordinates

Controller

uncertainty of a joint location

surrogate robot (robot A)

target robot (robot B)

encoder-decoder architecture



Poster design inspired by Mike Morrison



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arXiv:2412.1640



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