

VISION-BASED ESTIMATION OF GRASPING FORCES OF AGRI-FOOD GRIPPER

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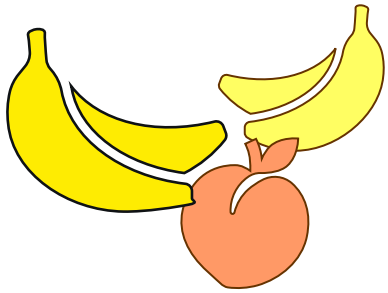
UNIVERSITY OF TWENTE,
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SEPTEMBER 2025

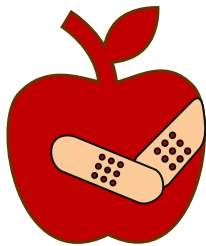


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CROP GRIPPING



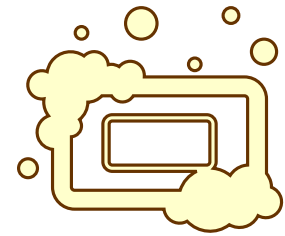
Variation



Fragile produce

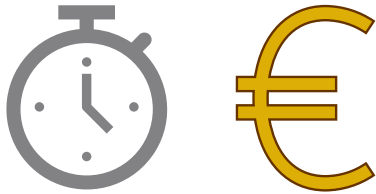


Environment

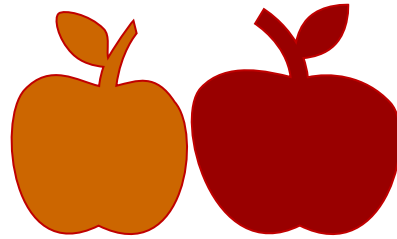


Hygiene

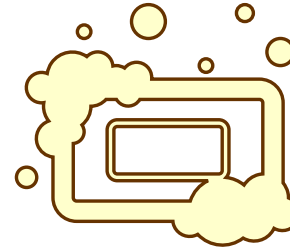
IDEAL GRIPPER



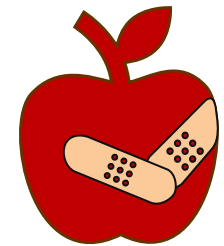
Cheap, easy to manufacture



Adapt to object shape

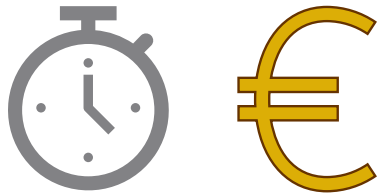
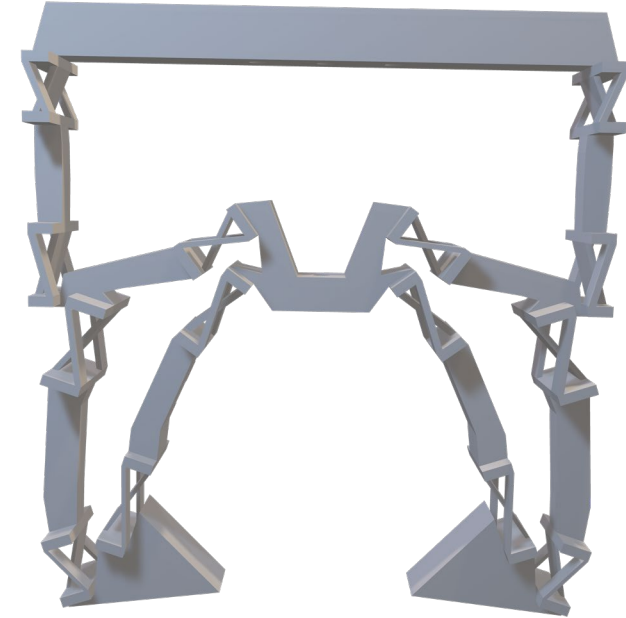


Cleanable/disposable

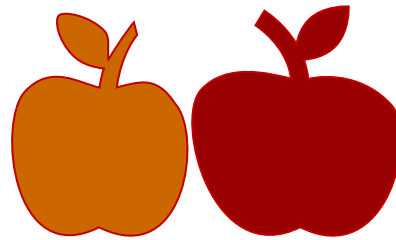


Prevent damage to
objects

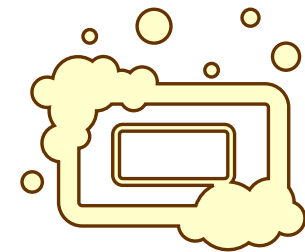
FLEXURE-BASED GRIPPER



Printable
cheap, easy manufacturing



Underactuated
adapts to object shape



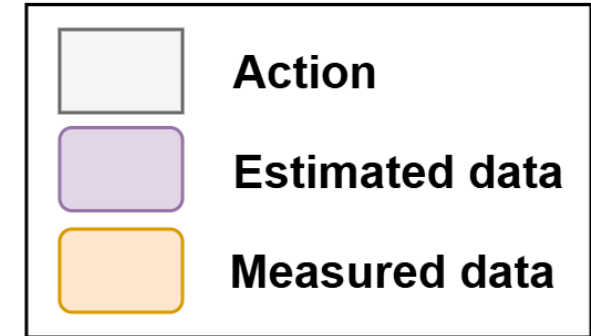
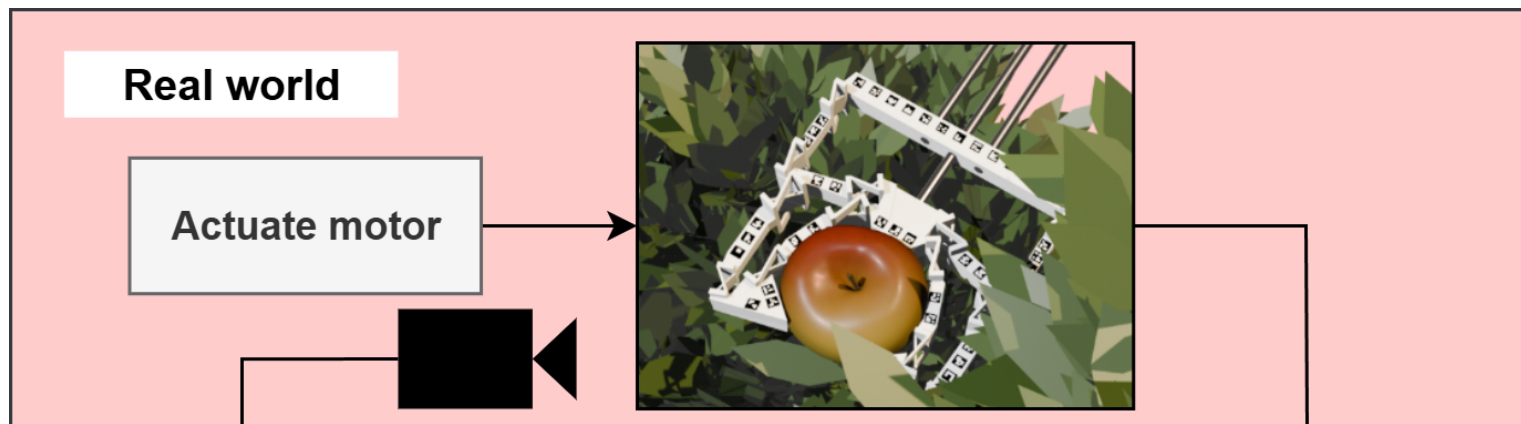
Easy to **clean**
and disposable

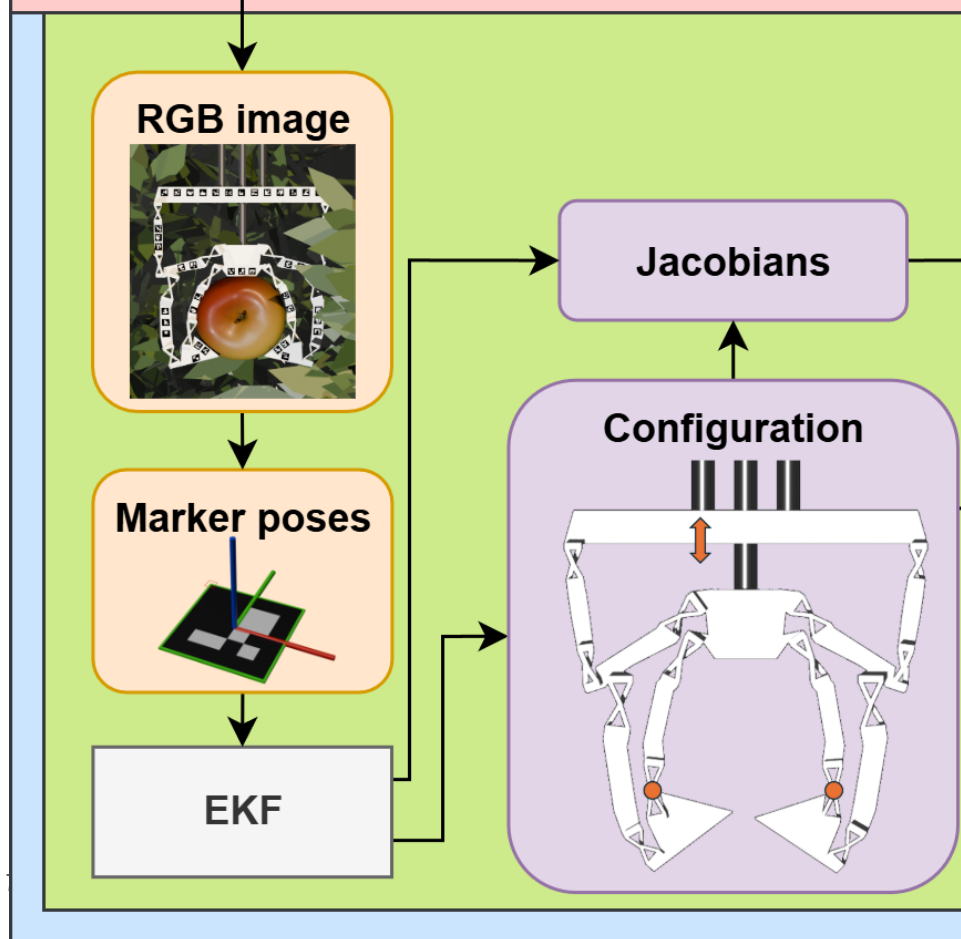
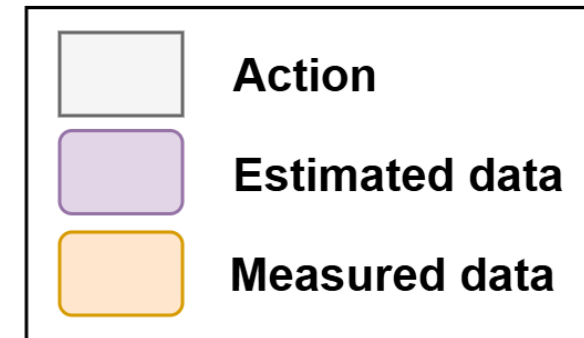
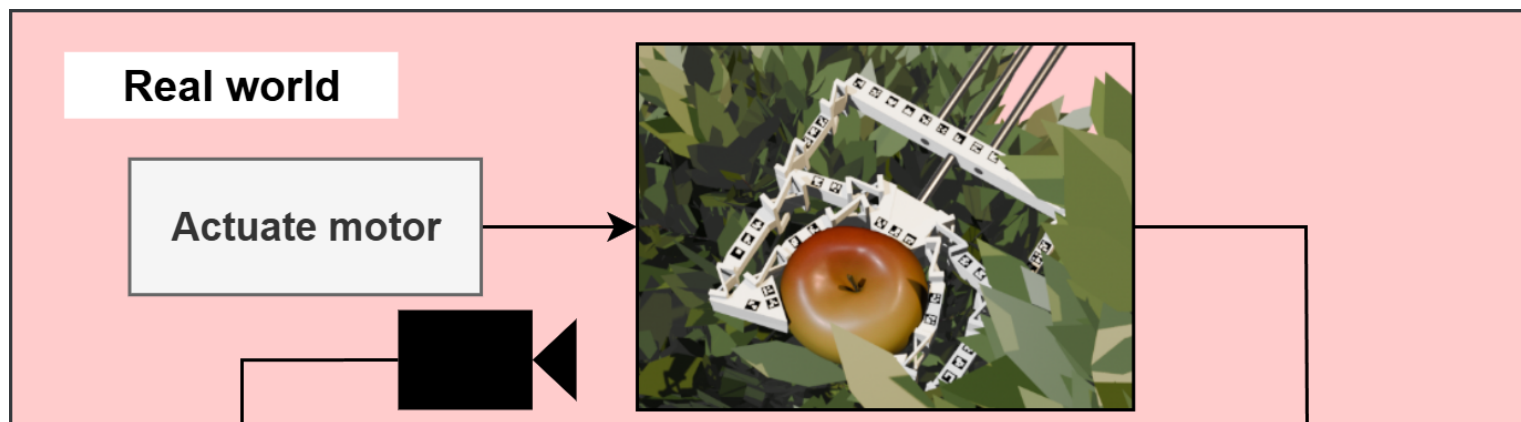
RESEARCH GOAL

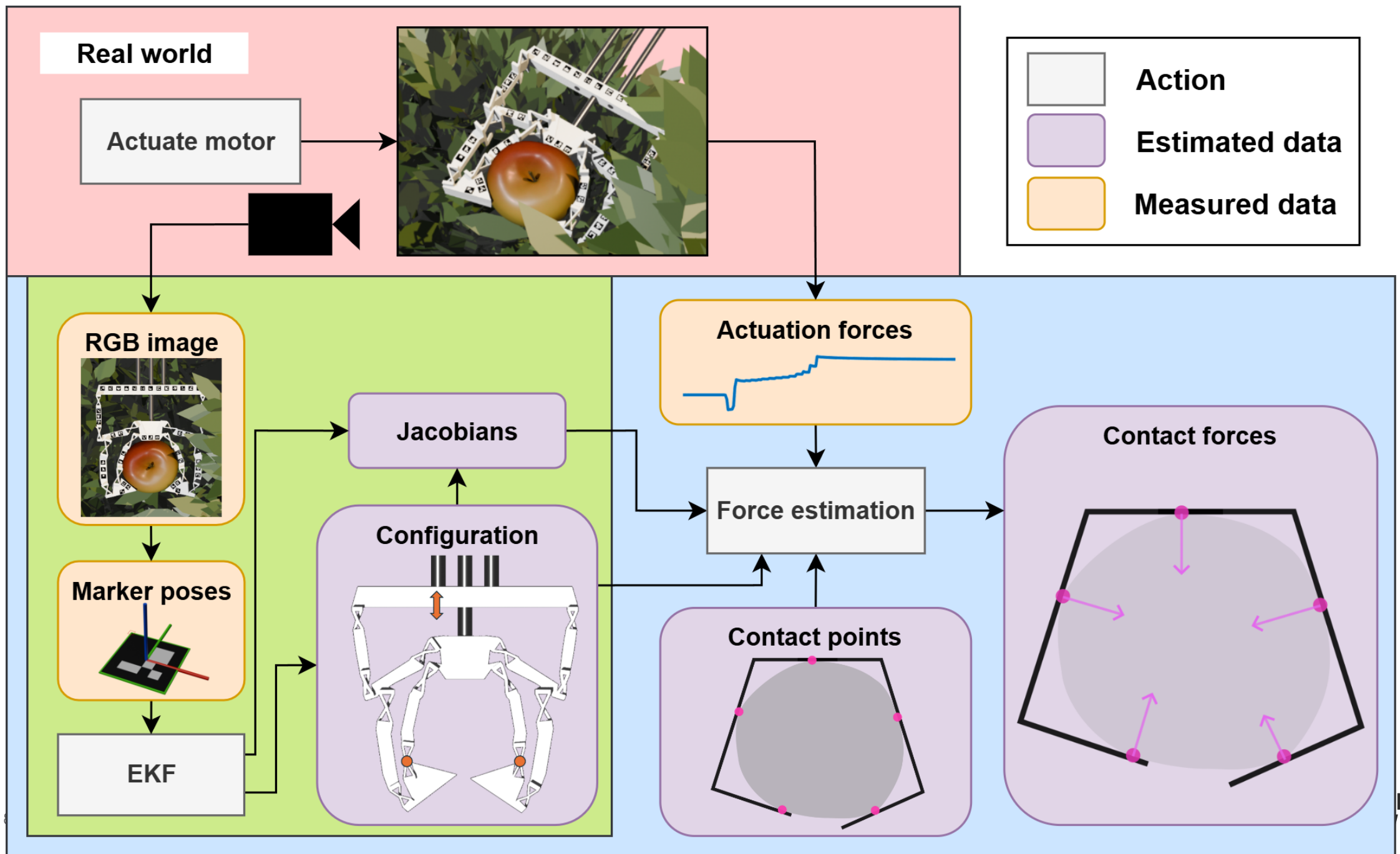
- Grasp object without damaging it
 - Need to know the contact forces we apply to the object

No force sensors at the contact positions

- Estimate contact forces using vision
- Needed
 - Gripper configuration
 - Contact points
 - Actuation force $f_{actuation}$
 - Joint stiffness

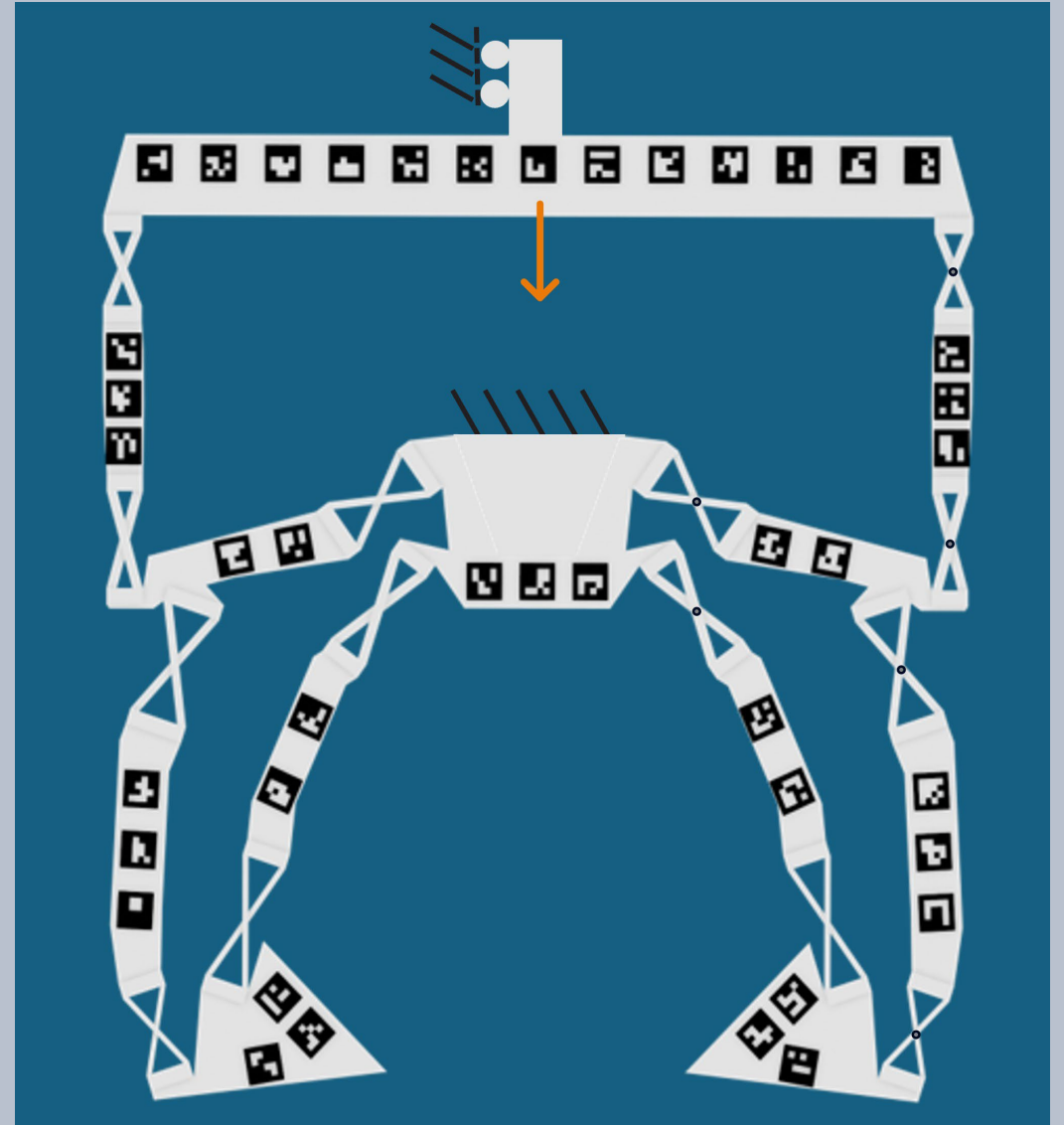






GRIPPER CONFIGURATION ESTIMATION

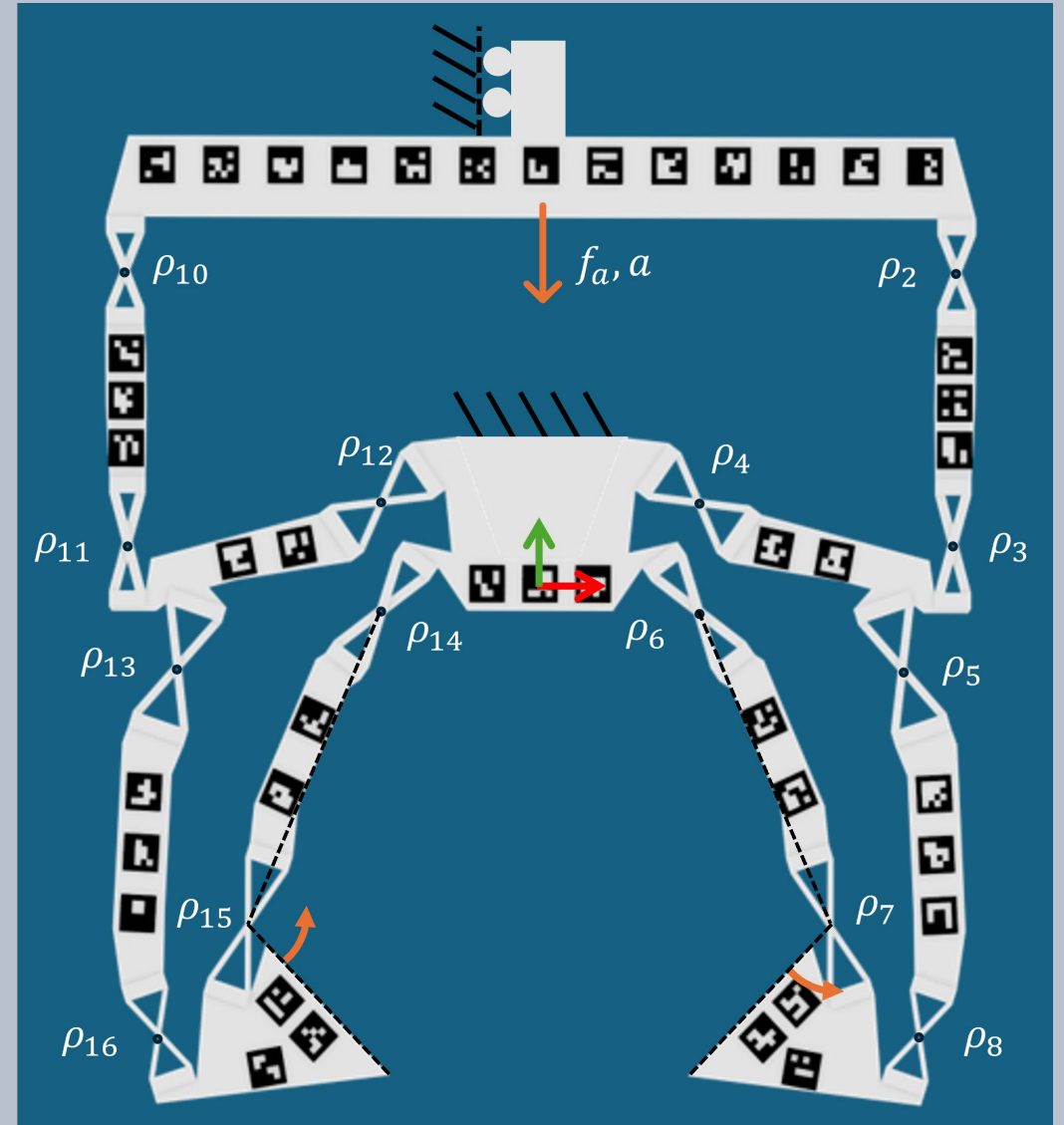
- Track markers on gripper
- Vast amount of markers
 - Account for partial occlusions



WHAT DO WE ESTIMATE?

- 3 degrees of freedom
 - 1 linear motion
 - 2 rotations
- Reference/fixed frame at marker

Variable	p_{ref}^c	q_{ref}^c	ϕ_7	ϕ_{15}	a
Dimensions	3x1	4x1	1	1	1



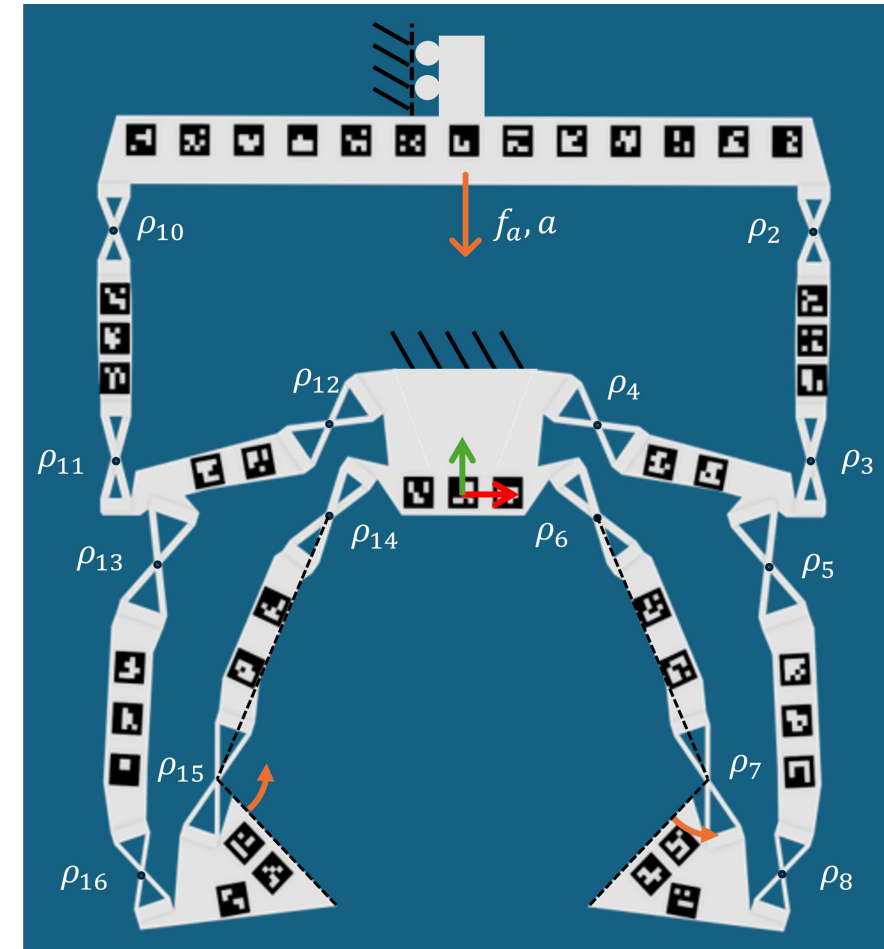
HOW DO WE ESTIMATE?

- Use Extended Kalman filter to estimate gripper configuration
 - “What do we expect to measure based on estimated states?”
 - Then compare to actual measurements → update states
- Describe marker pose in terms of joint angles

$$\mathbf{H}_m^{\text{ref}}(\boldsymbol{\phi}) = \left(\prod_i e^{\tilde{\mathbf{T}}_{\rho_i}^{\text{ref}, \rho_{i-1}} \phi_i} \right) \mathbf{H}_m^{\text{ref}}(0)$$

ρ_i : rotation point location i

ϕ_i : deflection angle at ρ_i



FORCE ESTIMATION

$$\mathbf{f}_c = [\mathbf{J}_d^c \quad \mathbf{J}_e^c]^{-\top} \left(\begin{bmatrix} \mathbf{J}_d^{\phi \top} \\ \mathbf{0}_{2 \times n} \end{bmatrix} \mathbf{K} \boldsymbol{\phi} - \begin{bmatrix} \mathbf{f}_d \\ \mathbf{f}_e \end{bmatrix} \right)$$

d : DoFs,

c : contact points

e : external forces on object

$\boldsymbol{\phi}$: deflection angles in gripper joints

\mathbf{K} : stiffness matrix of gripper joints

VALIDATION

Circular objects

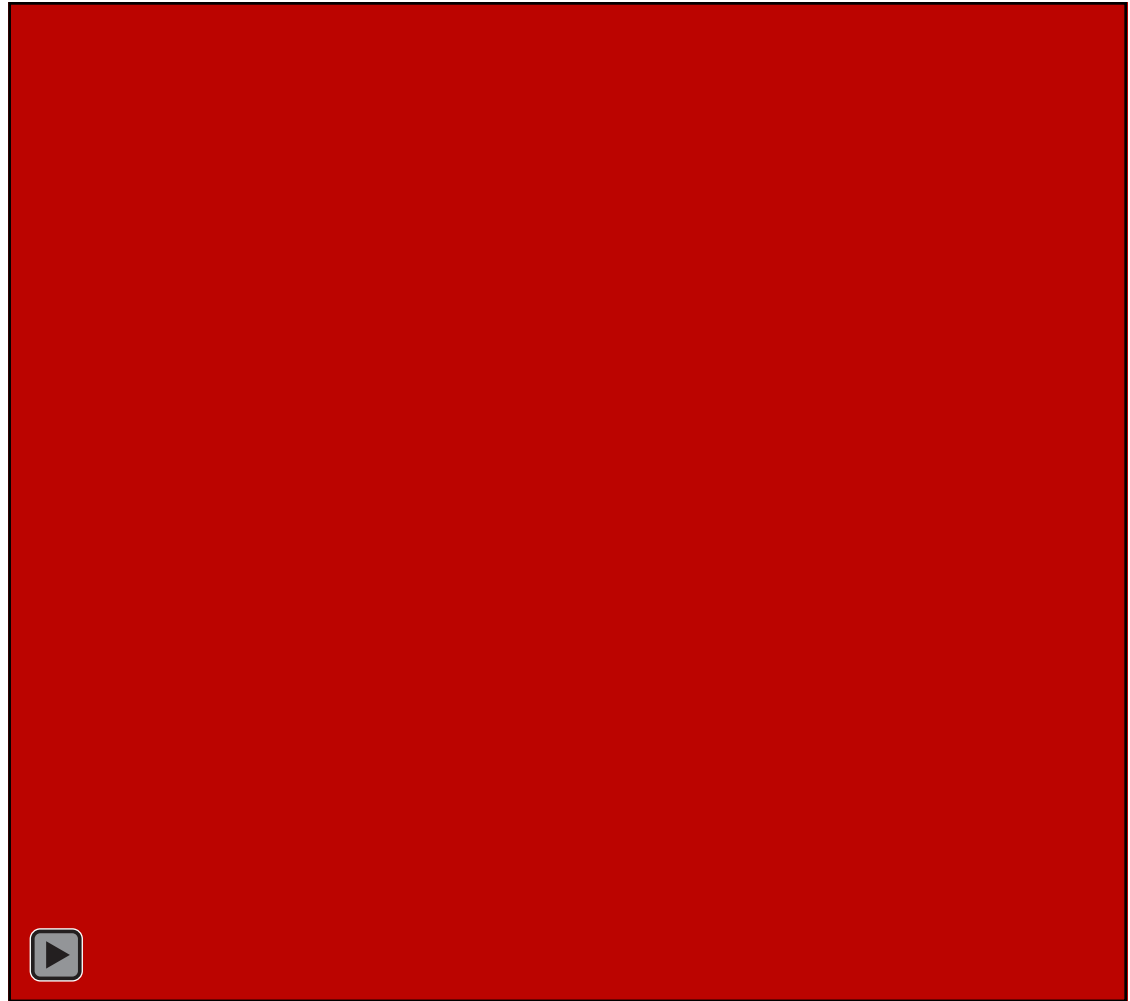
- Known contact points

→ calculate gripper configuration

“theoretical configuration”

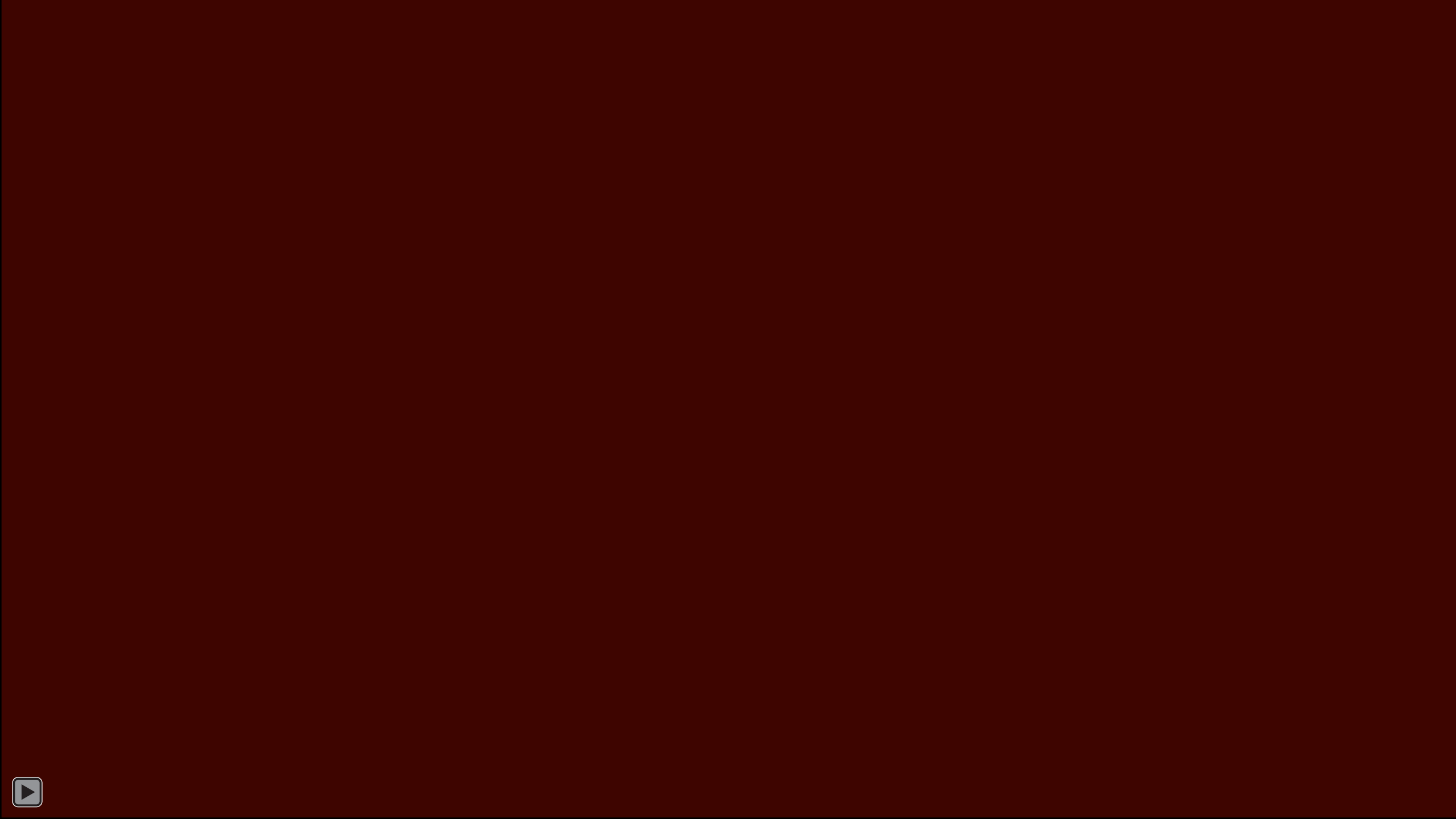
→ compute Jacobians

“theoretical contact forces”



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DISCUSSION

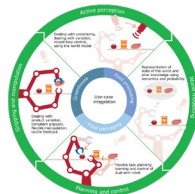
- Asymmetry in configuration results
 - Setup
 - Objects
- Gripper material
 - Shrinking/expanding
 - Marker size
- Use-case
 - External forces
 - Dynamics

CONCLUSIONS

- Vision based approach to estimate contact forces
 - Measure marker poses
 - Kinematic model of gripper
- Ideal gripper
- Method not limited to this gripper

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The Synergia project is organized and led by Wageningen University and Research in close cooperation with Next Food Collective as well as the Universities of Delft, Twente, Eindhoven, and Nijmegen. The authors have declared that no competing interests exist in the writing of this publication. Funding for this research was obtained from the Netherlands Organisation for Scientific Research (NWO grant 17626), IMEC-One Planet and other private parties