

Automatic evaluation of task-focused parallel jaw gripper design

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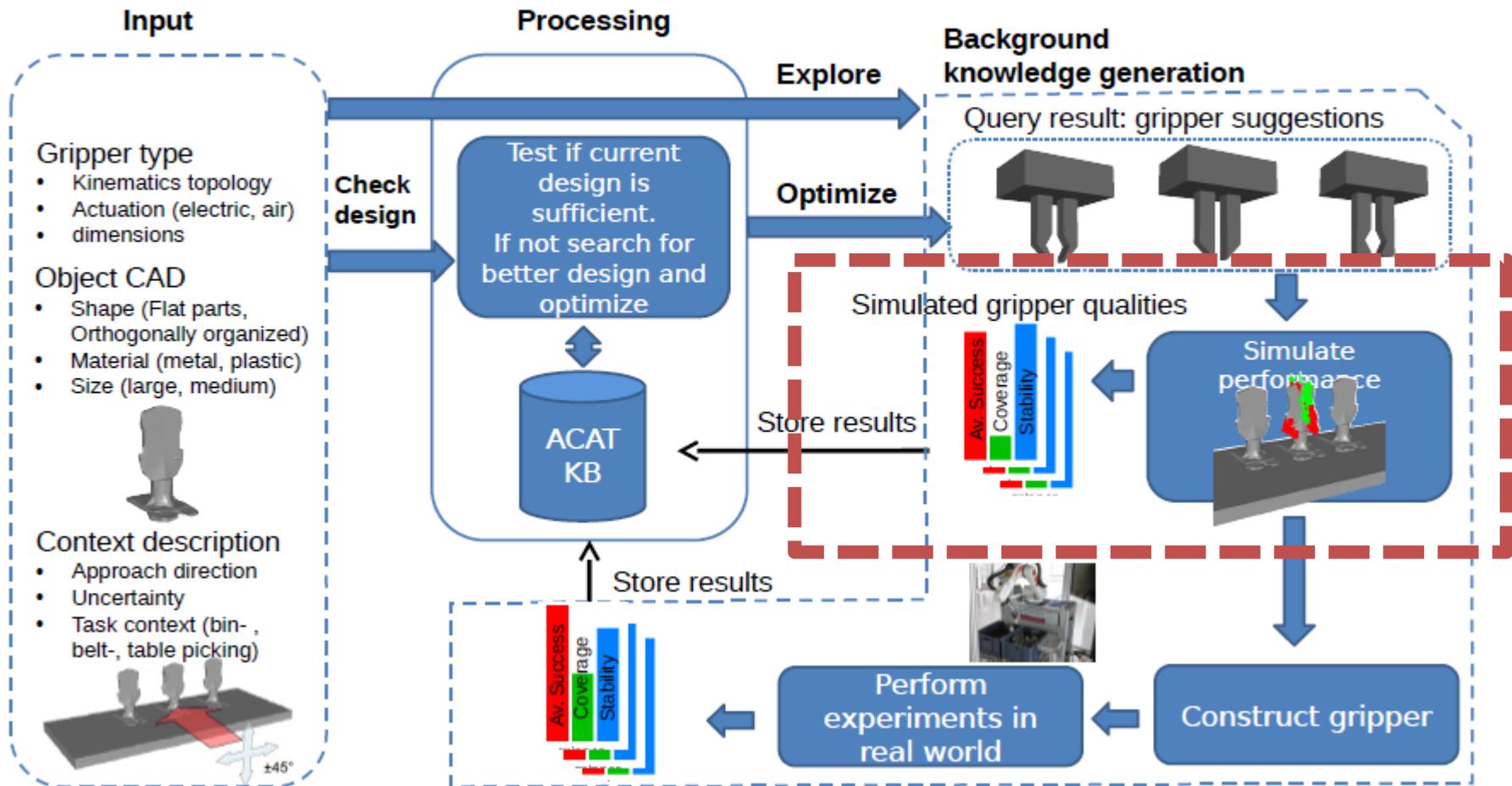


Motivation

- Faster & easier gripper design,
- Make robotic solutions easier to implement for smaller enterprises,
- More optimal gripper designs, faster cycle times, more economical production, ...



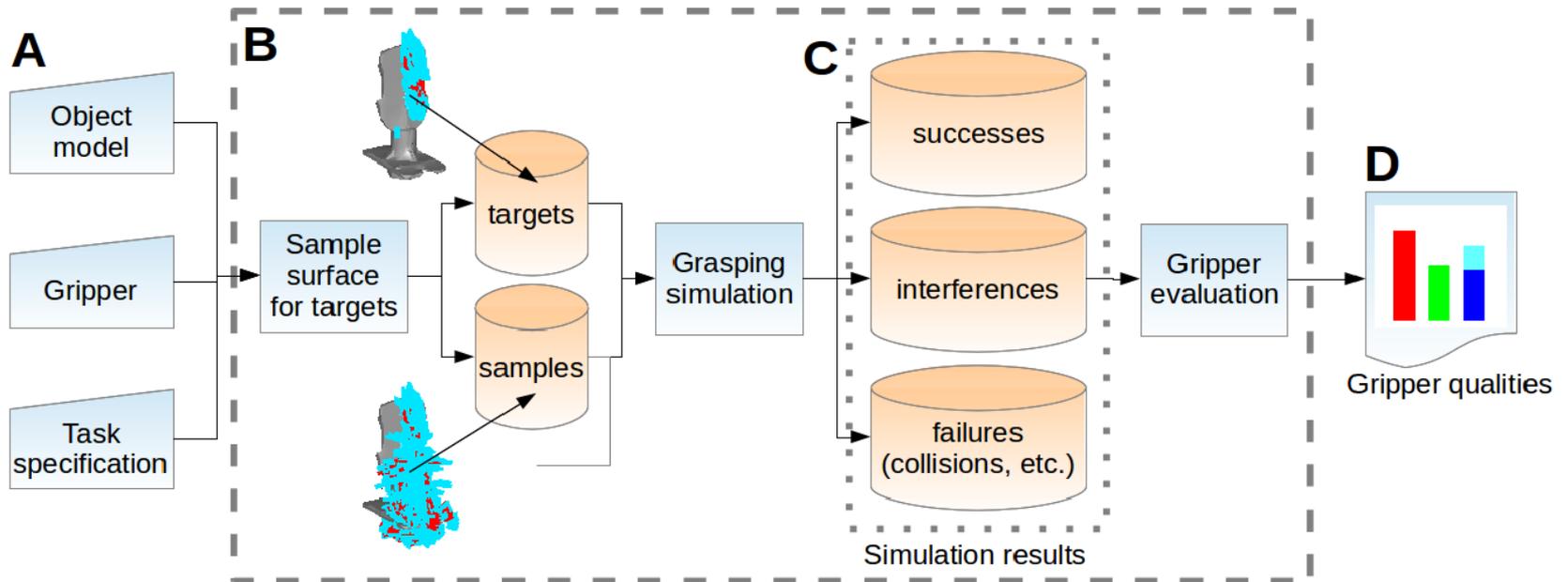
The big picture



Content

- Method overview
- Task context
- Gripper quality metrics
 - Success ratio
 - Coverage
 - Wrench
- Gripper parameterization
- Results

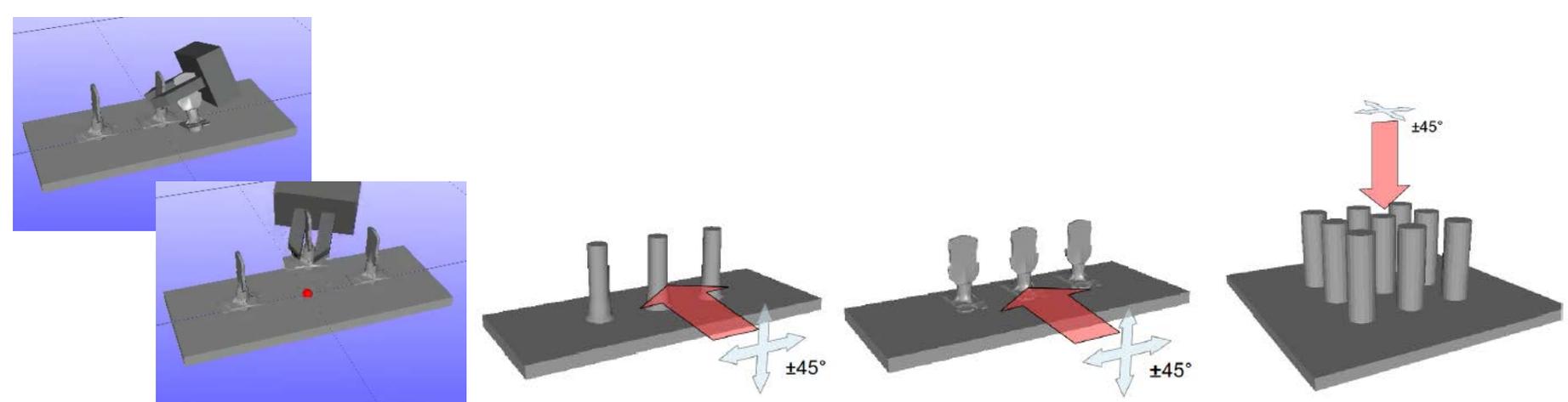
Method





Task context

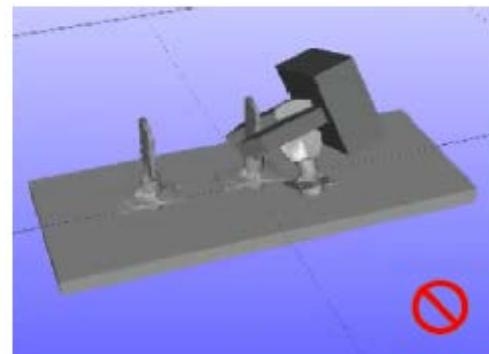
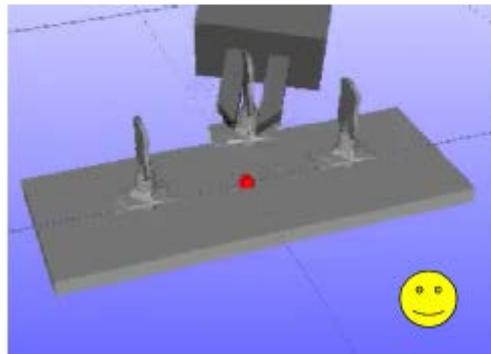
- Design is embedded in task
- Task context parameters:
 - Approach direction space box in 6D
 - Static environment
 - Dynamic environment



Gripper Quality Metrics

- **Success ratio** is the most intuitive metric. it's defined as a ratio of successful grasps to the total number of grasps representing the possible ideal grasp task space:

$$S = \frac{N_{successes}}{N_{filteredtargets}}$$

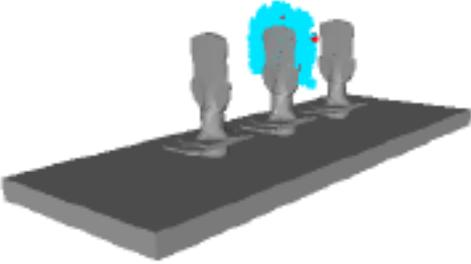


Gripper Quality Metrics

- **Coverage** is a measure of how well the success space covers all the possible approaches to object. It is calculated as:

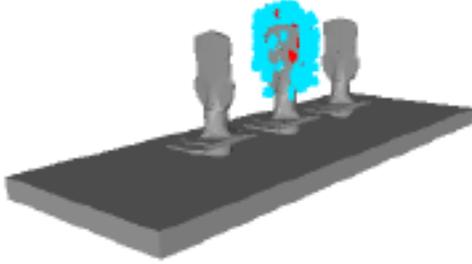
$$Q_{coverage} = \frac{N_{successes} + N_{interferences}}{N_{filtered\ samples}}$$

opening = 0.005



lower coverage

opening = 0.05



higher coverage

The diagram illustrates the concept of coverage in a robotic gripper. It shows two scenarios of a gripper approaching a rectangular block with three vertical posts. The gripper's success space is represented by a blue cloud of points. In the first scenario, the opening between the gripper fingers is 0.005, resulting in a sparse success space and lower coverage. In the second scenario, the opening is 0.05, resulting in a denser success space and higher coverage. The equation above shows that coverage is calculated as the sum of successful approaches and interferences, divided by the total number of filtered samples.

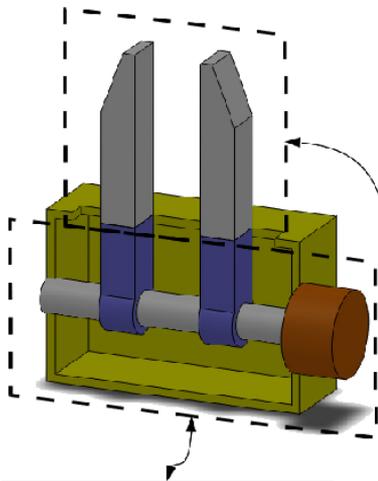
Gripper Quality Metrics

- **Wrench** metric describes how firm the grasps are on average, i.e. how high a force (or torque) has to be applied to dislodge object from gripper. Two values are calculated:
 - Average wrench: average wrench from all of the successful grasps
 - Top wrench: average wrench of the top 20% grasps (wrench-wise)

Gripper parameterization

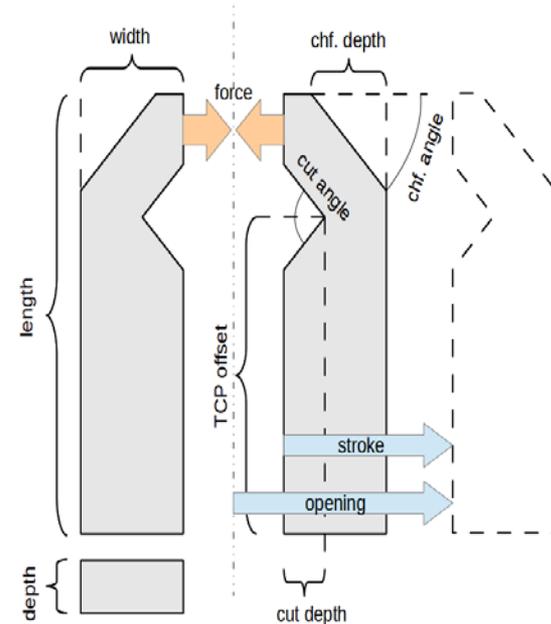
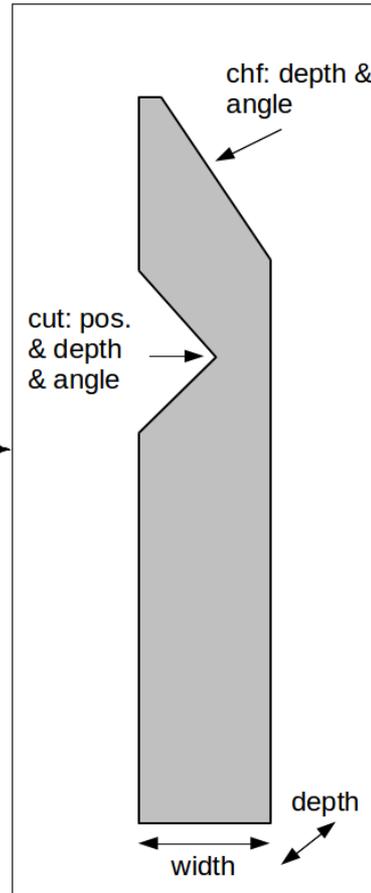
Gripper Design

- weight
- dimensions



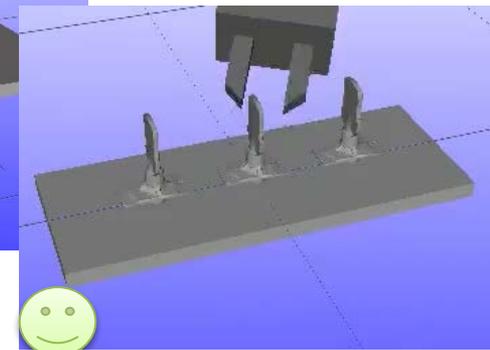
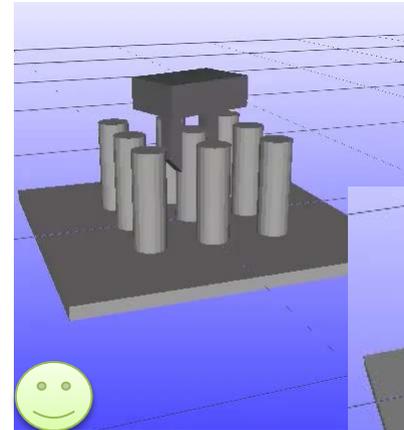
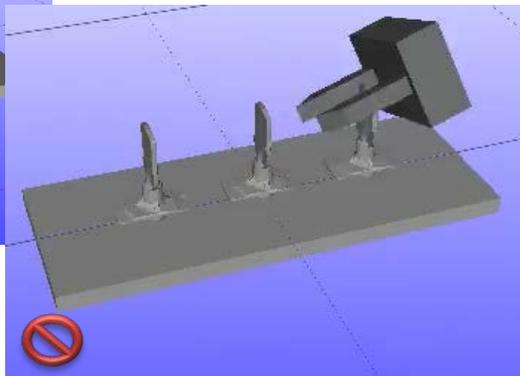
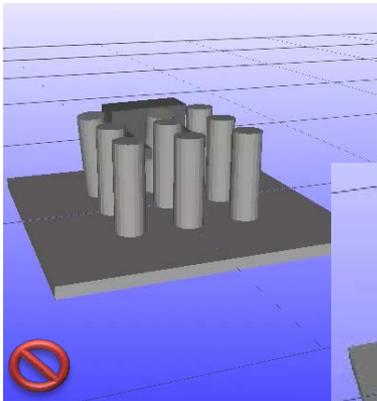
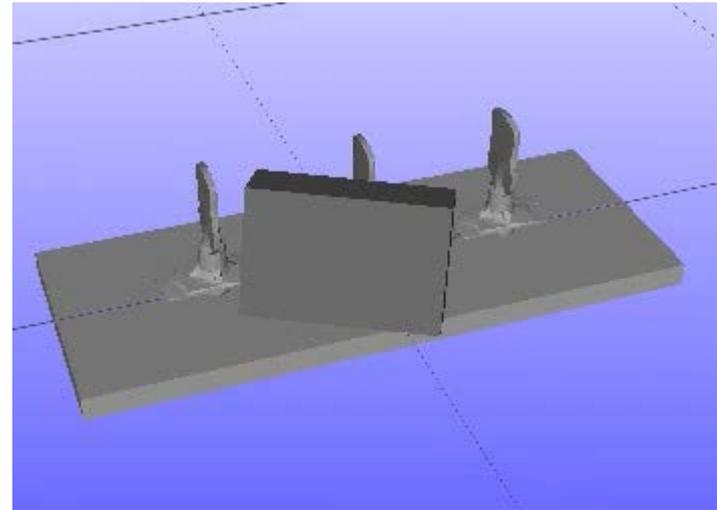
Kinematic design

- motor force
- motor velocity
- motor acceleration
- stroke
- movement



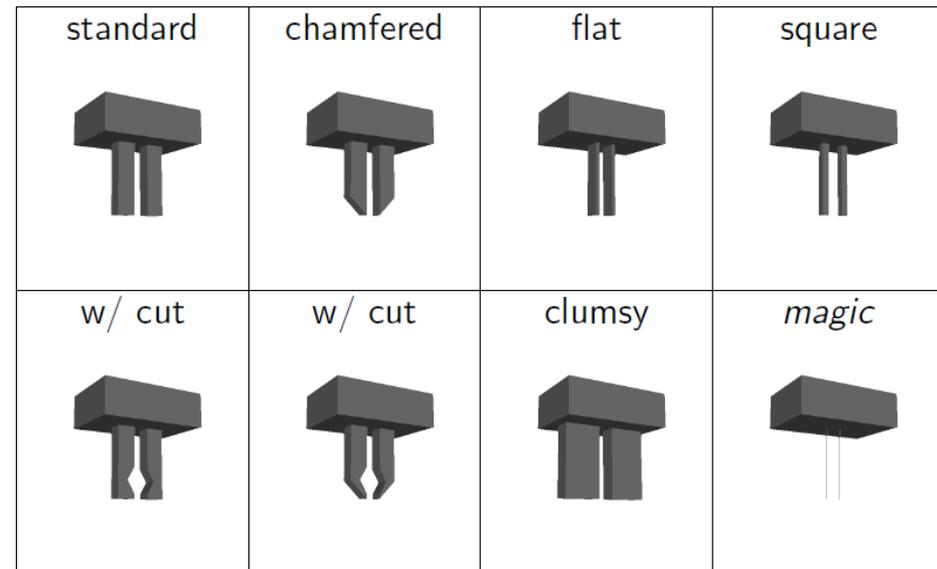
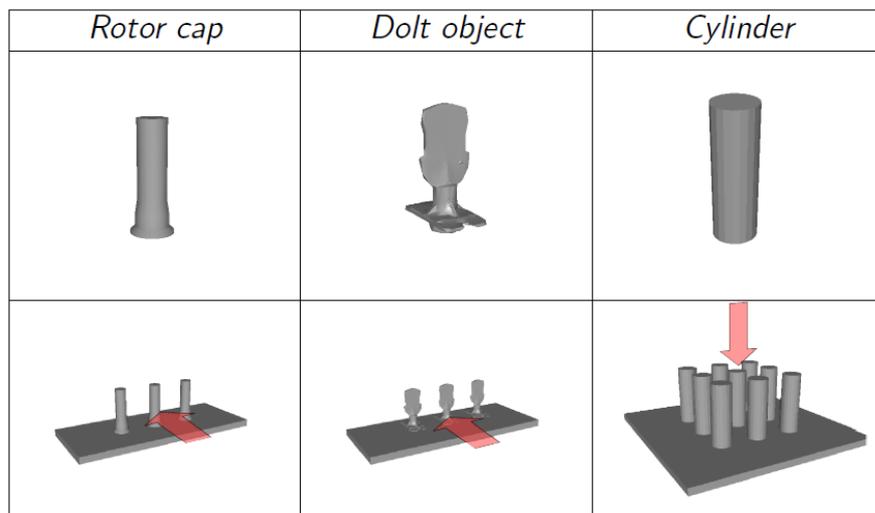
Grasp: good, bad and *ugly*

- Possible grasp outcomes
 - Success
 - Miss
 - Collision
 - Interference

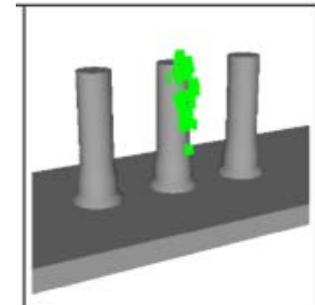


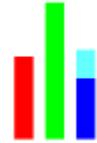
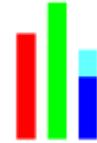
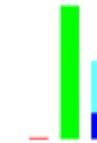
Results

- Experimental setup
 - 8 different grippers
 - Three different objects and task contexts



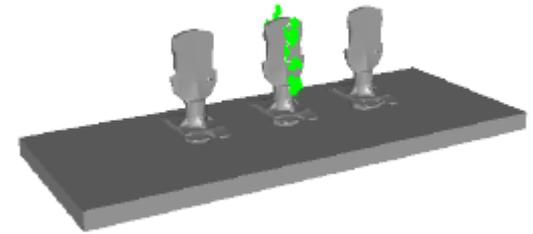
Results



									
$\frac{S}{C}$ $\frac{W}{T}$									
S	0.80855	0.808682	0.933106	0.918616	0.784407	0.781222	0.471071	0.93237	0.93237
C	0.410045	0.40695	0.405354	0.409105	0.395201	0.396244	0.414438	0.409291	0.409291
W	4.05757	3.96747	4.32704	2.57689	5.37023	5.34184	4.17798	0.430175	0.430175
T	5.57289	5.58455	6.17223	4.12499	8.79734	8.79507	6.09341	1.69045	1.69045



Results

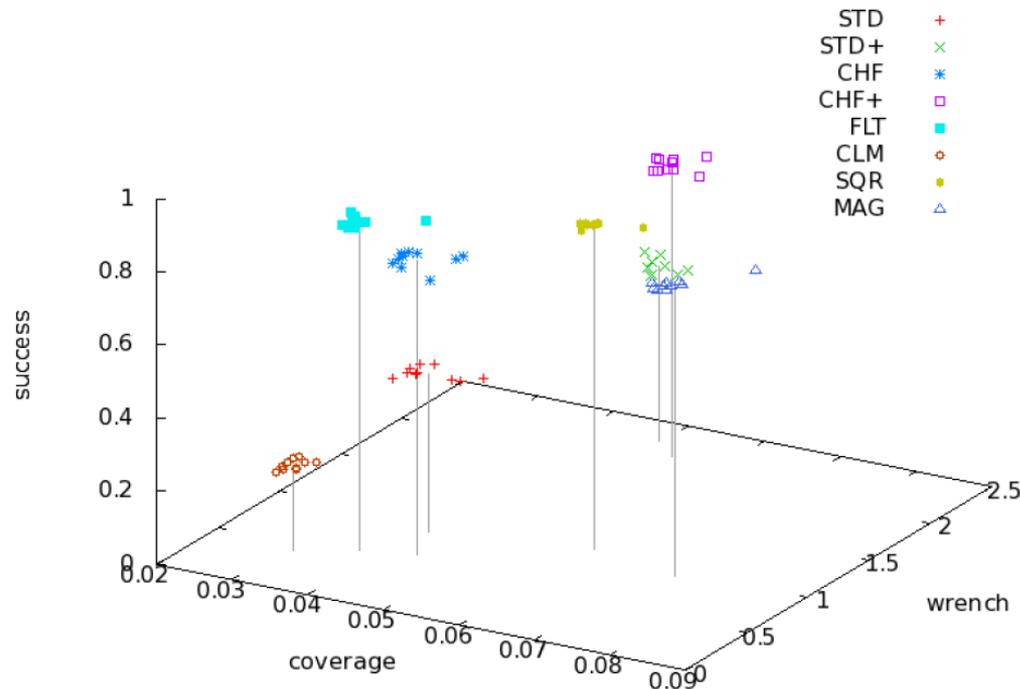


								
S C W/T								
S	0.939947	0.940407	0.942339	0.891838	0.922618	0.917325	0.353181	0.811189
C	0.0384534	0.0404457	0.0312942	0.0519822	0.044181	0.0473644	0.034295	0.064556
W	0.795429	0.768485	0.700768	1.20989	2.28268	2.3259	1.00931	1.00339
T	3.81162	3.69687	3.46404	3.58231	5.2667	5.30093	4.45606	3.28023



Results

- On repeatability
- Quality metric indices separation for Dolt scene:



Conclusion

- The method to evaluate parallel jaw grippers performance in specific grasping scenarios was developed
- Three gripper quality metrics are proposed
- Experiments were performed with several hand-designed gripper shapes to test proposed method's performance
- It is possible to evaluate a gripper design using simulated experiments

What's next

- Integrate into optimization loop
- Extend on task context classification
- Investigate performance of metrics in real life
- Extend gripper search to more generic gripper types: actuated and underactuated hands, more fingers, ...