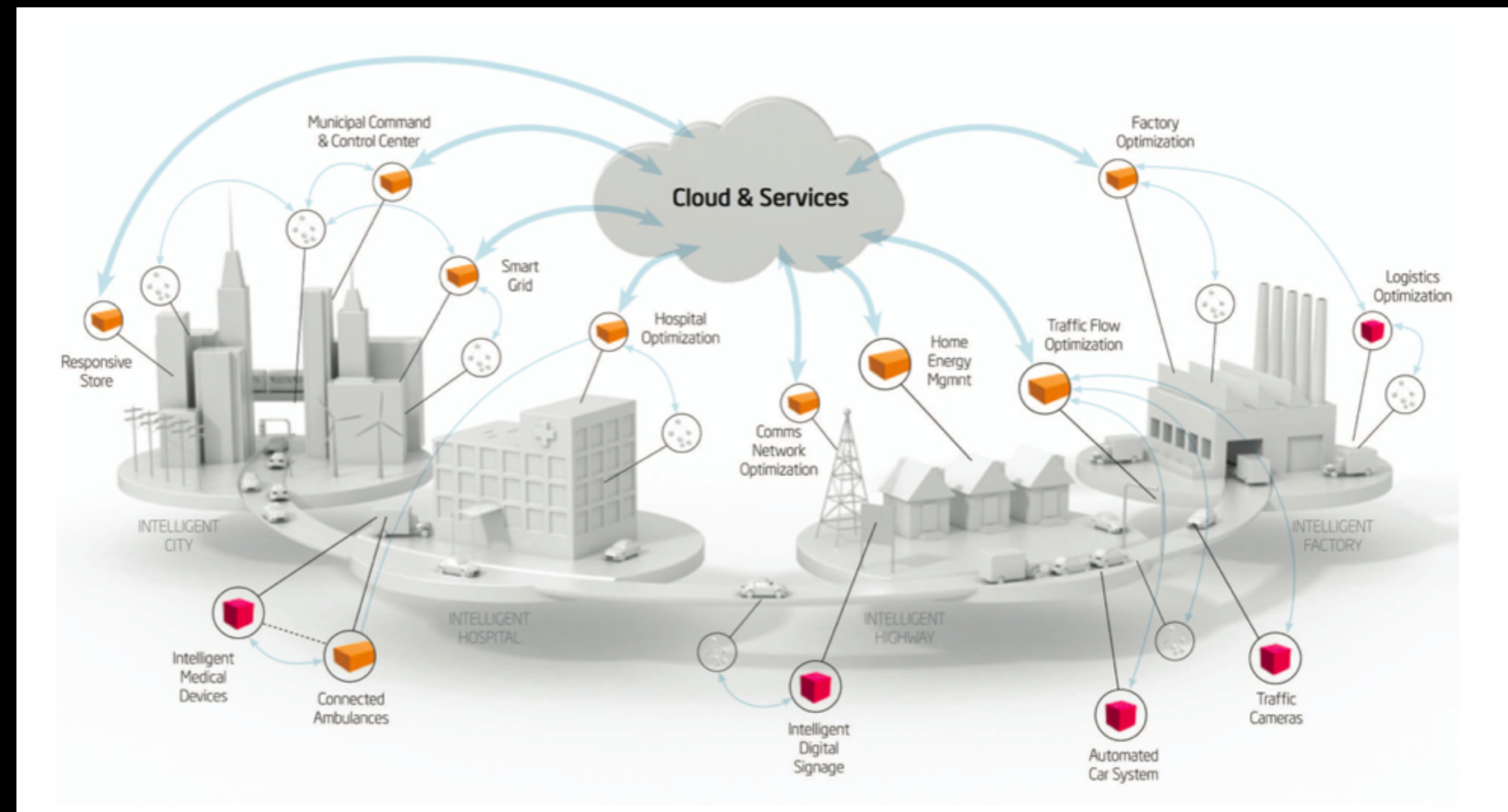
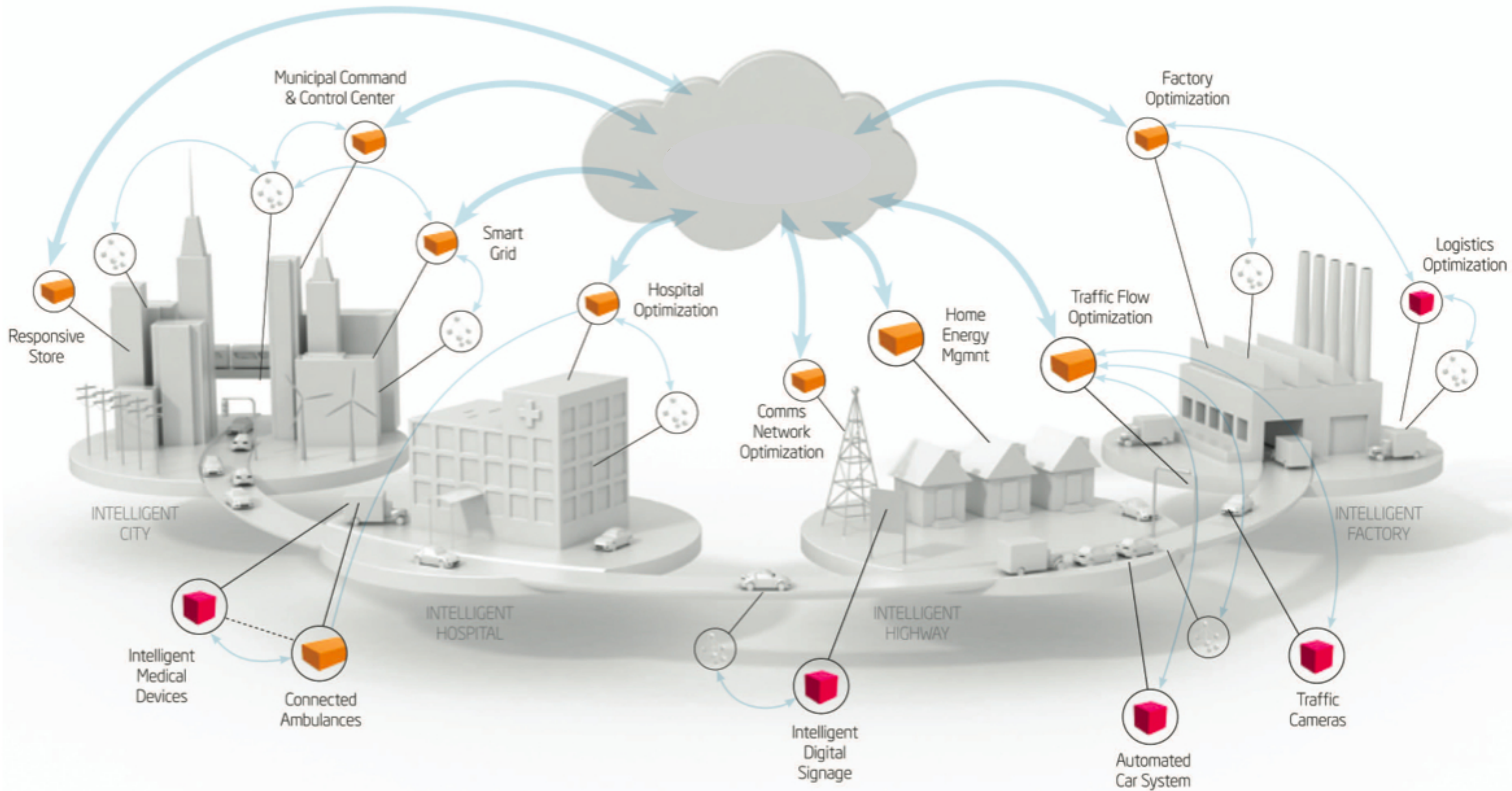


# IEEE/NSF WORKSHOP ON CLOUD MFG AND AUTOMATION



DEZHEN SONG, KEN GOLDBERG, ANI HSIEH



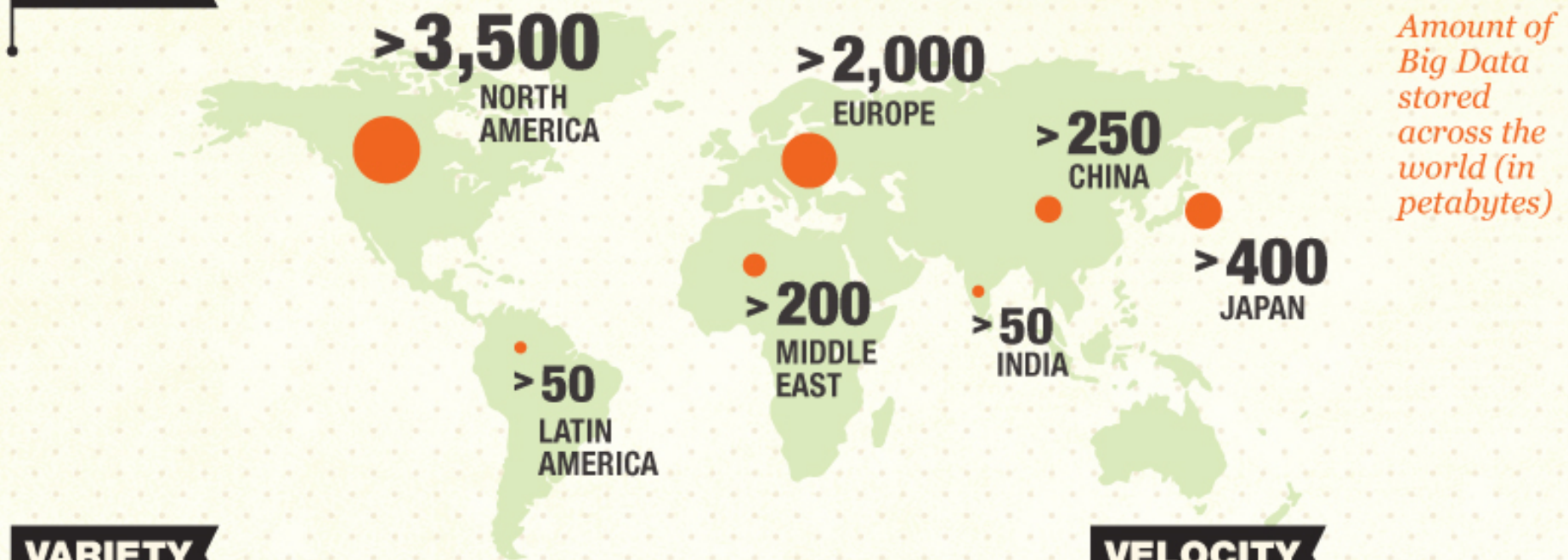
# BIG DATA

Big Data is data that is too large, complex and dynamic for any conventional data tools to capture, store, manage and analyze.

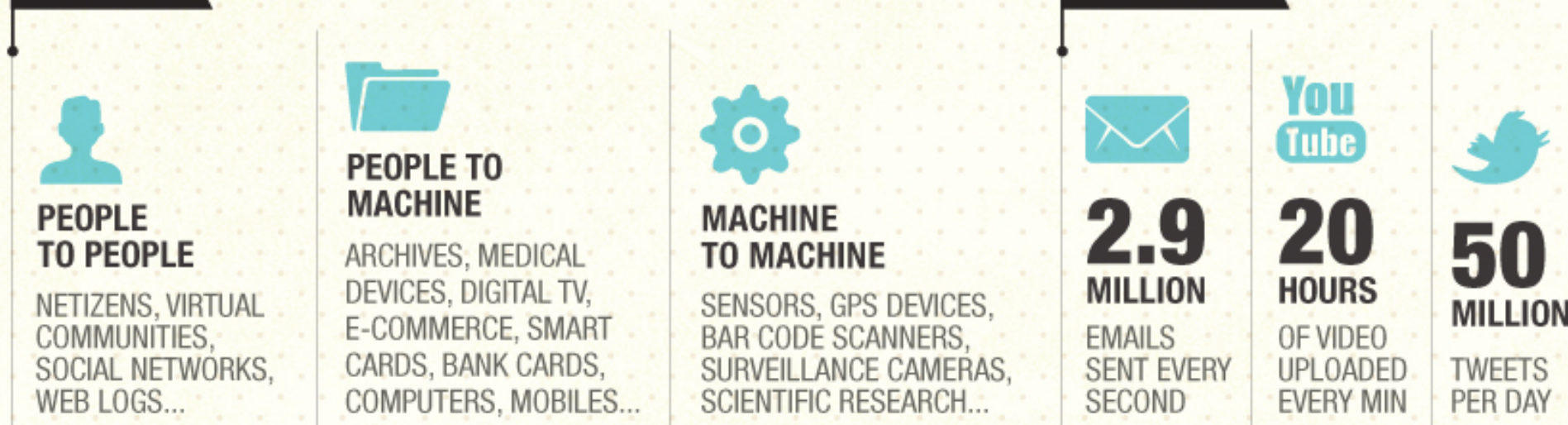
The right use of Big Data allows analysts to spot trends and gives niche insights that help create value and innovation much faster than conventional methods.

The "three V's", i.e the Volume, Variety and Velocity of the data coming in is what creates the challenge.

## VOLUME

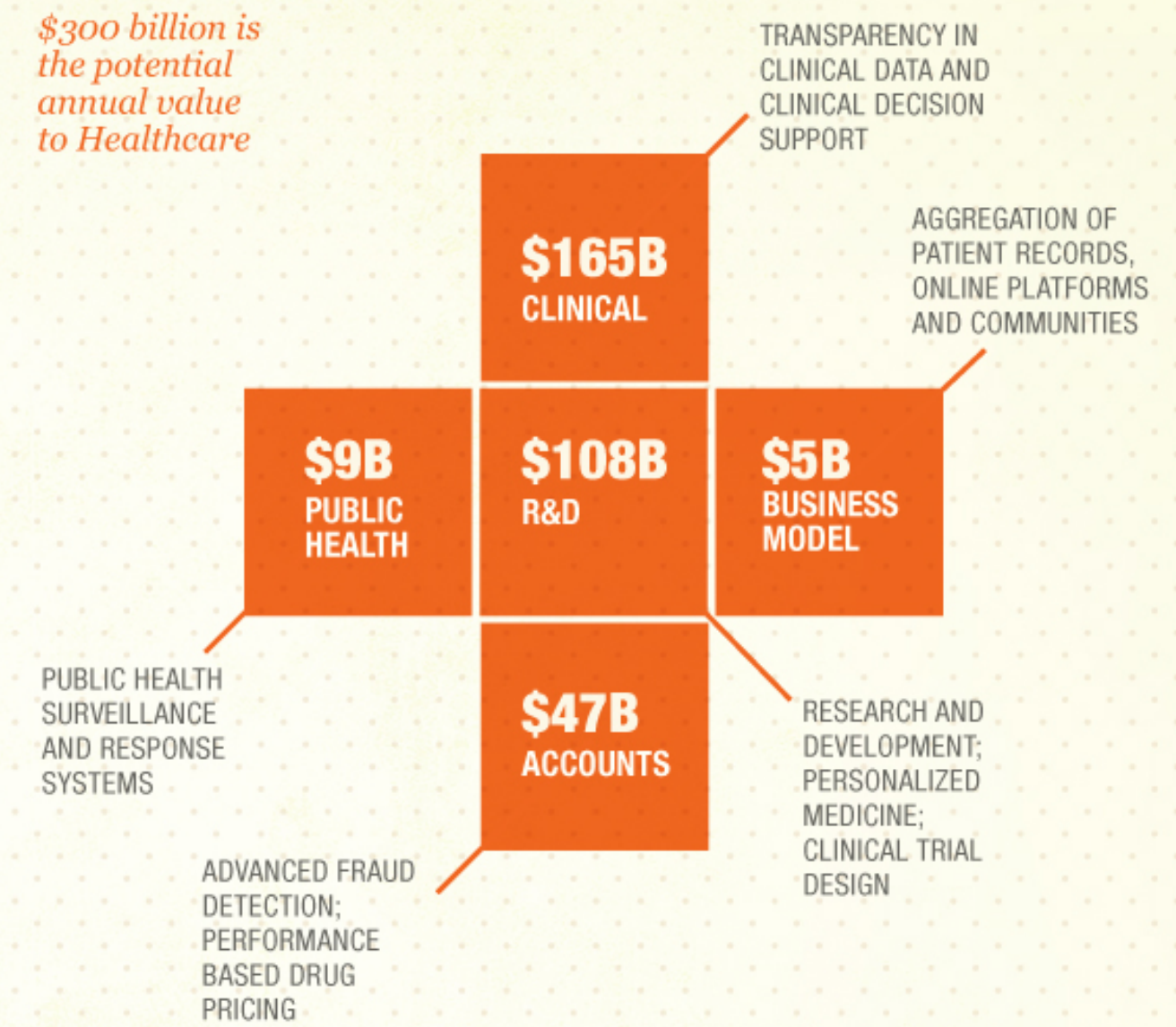


## VARIETY

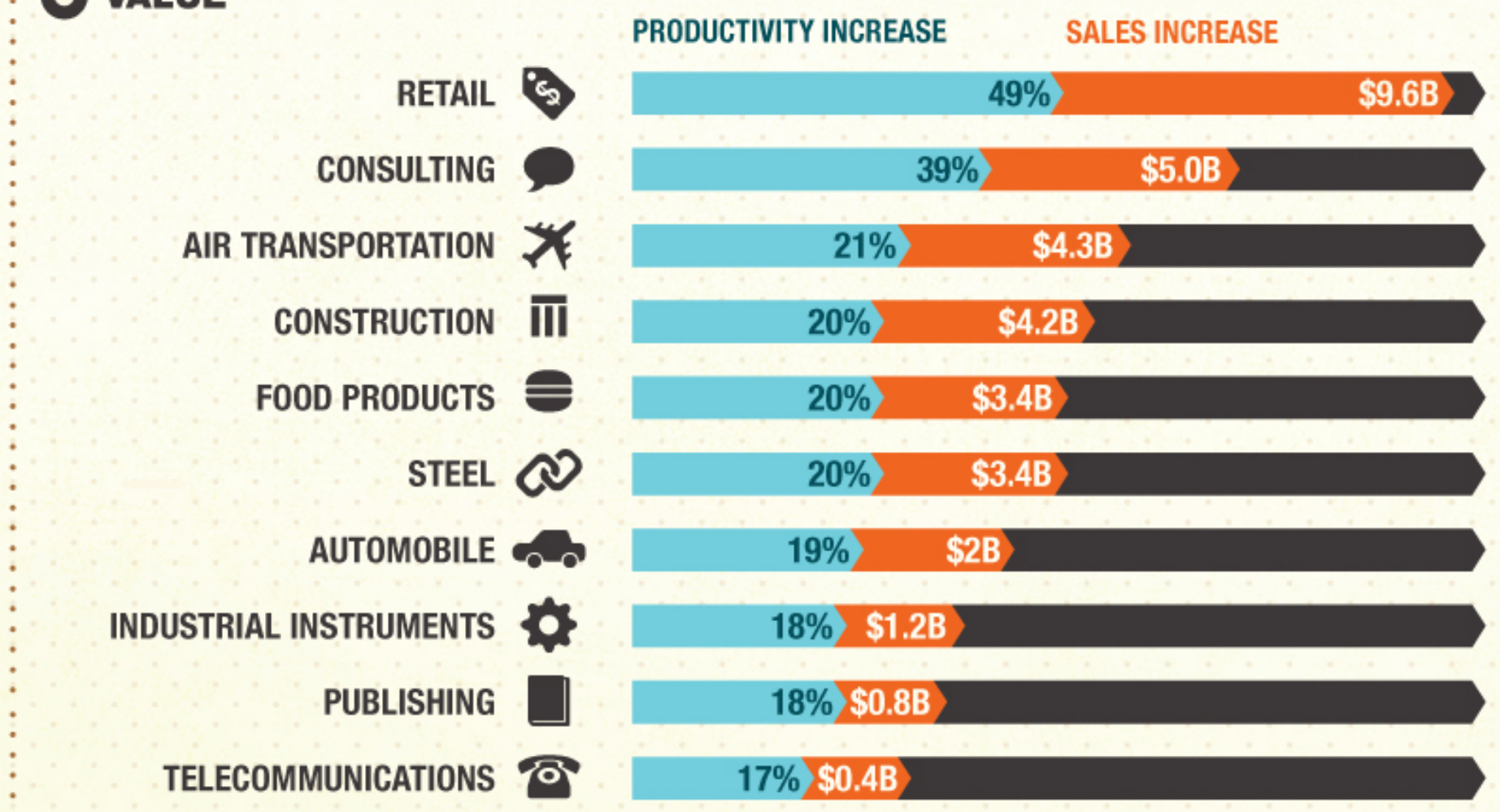


## CASE STUDY - Healthcare

\$300 billion is the potential annual value to Healthcare



## VALUE



40% PROJECTED GROWTH IN GLOBAL DATA CREATED PER YEAR



5% PROJECTED GROWTH IN GLOBAL IT SPENDING PER YEAR

The estimated size of the digital universe in 2011 was 1.8 zettabytes. It is predicted that between 2009 and 2020, this will grow 44 fold to 35 zettabytes per year. A well defined data management strategy is essential to successfully utilize Big Data.

Sources - 1 Reaping the Rewards of Big Data - Wipro Report 2 Big Data: The Next Frontier for Innovation, Competition and Productivity - McKinsey Global Institute Report 3 comScore, Radicati Group 4 Measuring the Business Impacts of Effective Data - study by University of Texas, Austin 5 US Department of Labour.

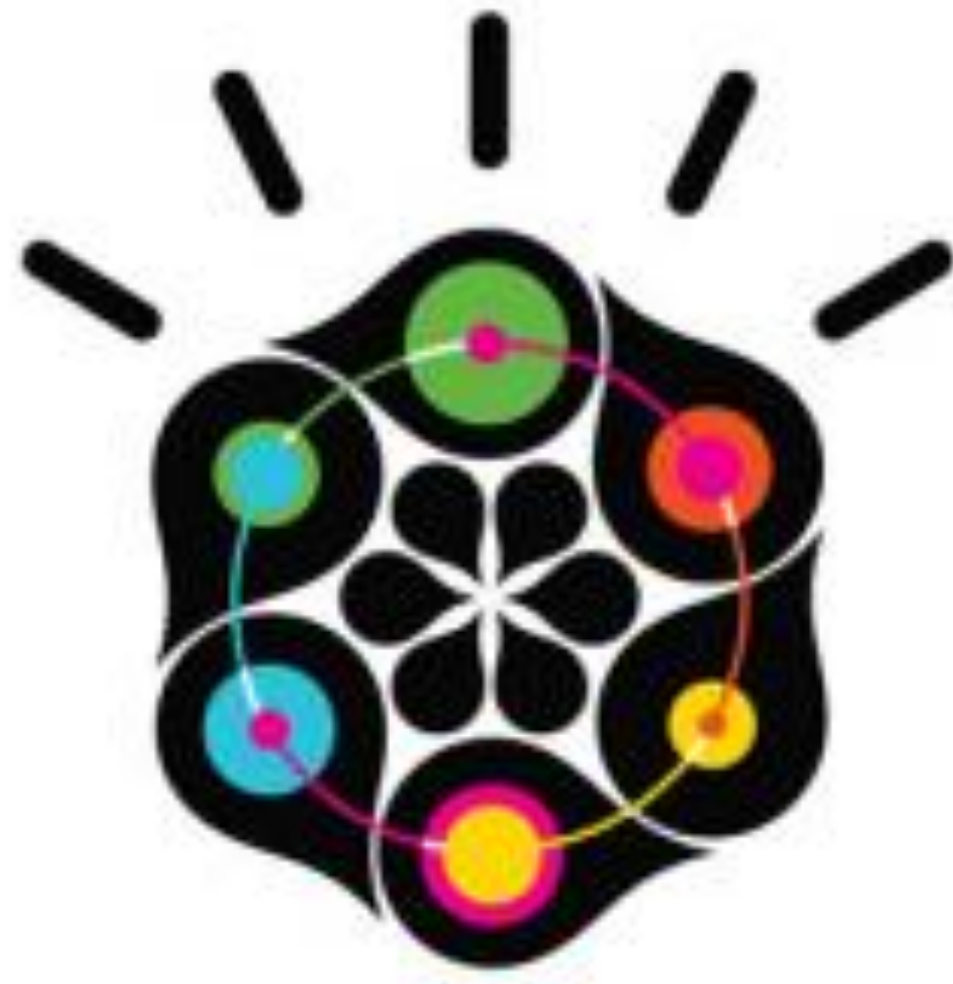
DO BUSINESS BETTER

NYSE:WIT | OVER 130,000 EMPLOYEES | 54 COUNTRIES | CONSULTING | SYSTEM INTEGRATION | OUTSOURCING





Smarter Energy



Smarter Oil



Smarter Public Safety



Smarter Food



Smarter Education



Smarter Cities

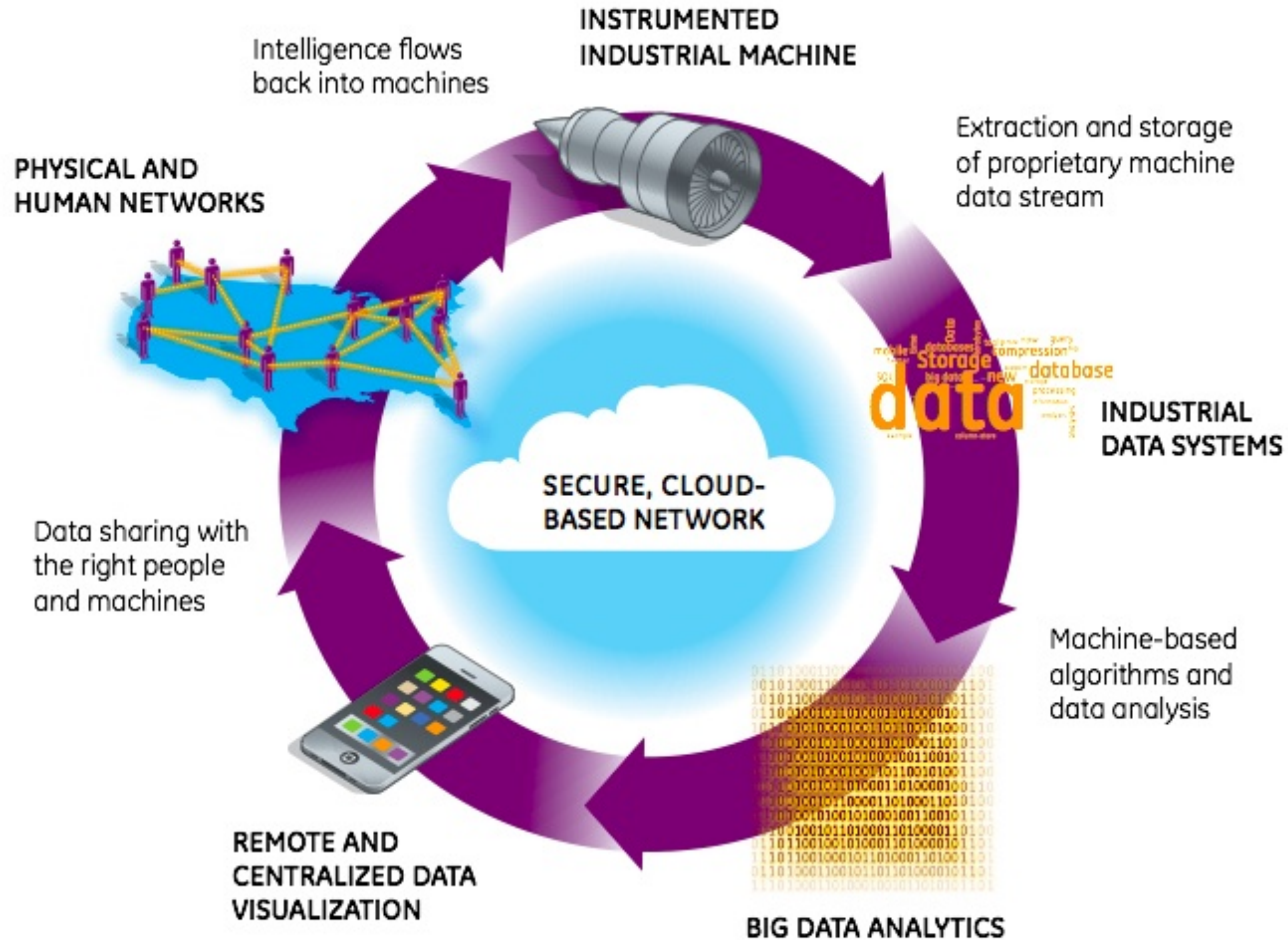


# iPhone Product Timeline

## Apple & Samsung



# GE: "INDUSTRIAL INTERNET" (FALL 2012)



OUTLINE

5 ELEMENTS OF CLOUD AUTO.

CLOUD-BASED GRASPING











# 5 ELEMENTS OF CLOUD AUTOMATION



1. BIG DATA: IMAGES, MAPS, MODELS
2. CLOUD COMP.: EC2 FOR STATISTICAL LEARNING
3. OPEN-SOURCE: HUMANS SHARING CODE, DATA, DESIGNS
4. COLLECTIVE ROBOT LEARNING:  
MACHINES SHARING DATA, OUTCOMES
5. CROWDSOURCING AND CALL CENTERS:  
OFFLINE AND ON-DEMAND HUMAN GUIDANCE

## RELATED WORK:

- [19] RAJESH ARUMUGAM, V.R. ENTI, LIU BINGBING, WU XIAOJUN, KRISHNAMOORTHY BASKARAN, F.F. KONG, A.S. KUMAR, K.D. MENG, AND G.W. KIT. DAVINCI: A CLOUD COMPUTING FRAMEWORK FOR SERVICE ROBOTS. IN IEEE INTERNATIONAL CONFERENCE ON ROBOTICS AND AUTOMATION, PAGES 3084{3089. IEEE, 2010.
- [20] LUIGI ATZORI, ANTONIO IERA, AND GIACOMO MORABITO. THE INTERNET OF THINGS: A SURVEY. COMPUTER NETWORKS, 54(15):2787{2805, OCTOBER 2010.
- [21] DMITRY BERENSON, PIETER ABBEEL, AND KEN GOLDBERG. A ROBOT PATH PLANNING FRAMEWORK THAT LEARNS FROM EXPERIENCE. IEEE INTERNATIONAL CONFERENCE ON ROBOTICS AND AUTOMATION, PAGES 3671{3678, MAY 2012.
- [22] BHARAT BHARGAVA, PELIN ANGIN, AND LIAN DUAN. A MOBILE-CLOUD PEDESTRIAN CROSSING GUIDE FOR THE BLIND. IN INTERNATIONAL CONFERENCE ON ADVANCES IN COMPUTING & COMMUNICATION, 2011.
- [23] MATEI CIOCARLIE, KAIJEN HSIAO, E. G. JONES, SACHIN CHITTA, R.B. RUSU, AND I.A. SUCAN. TOWARDS RELIABLE GRASPING AND MANIPULATION IN HOUSEHOLD ENVIRONMENTS. IN INTL. SYMPOSIUM ON EXPERIMENTAL ROBOTICS, PAGES 1{12, NEW DELHI, INDIA, 2010.
- [24] MATEI CIOCARLIE, CAROLINE PANTOFARU, KAIJEN HSIAO, GARY BRADSKI, PETER BROOK, AND ETHAN DREYFUSS. A SIDE OF DATA WITH MY ROBOT. IEEE ROBOTICS & AUTOMATION MAGAZINE, 18(2):44{57, JUNE 2011.
- [30] ZHIHUI DU, WEIQIANG YANG, YINONG CHEN, XIN SUN, XIAOYING WANG, AND CHEN XU. DESIGN OF A ROBOT CLOUD CENTER. IN INTERNATIONAL SYMPOSIUM ON AUTONOMOUS DECENTRALIZED SYSTEMS, PAGES 269{275. IEEE, MARCH 2011.
- [39] ERIC GUIZZO. CLOUD ROBOTICS: CONNECTED TO THE CLOUD, ROBOTS GET SMARTER, 2011.

## WEBSITE, SURVEY OF RELEVANT REFERENCES:

[HTTP://GOLDBERG.BERKELEY.EDU/CLOUD-ROBOTICS/](http://goldberg.berkeley.edu/cloud-robotics/)

OUTLINE

INTRO: 5 ELEMENTS

CLOUD-BASED GRASPING

# ALGORITHMIC AUTOMATION

DEFINE SET OF ADMISSIBLE PARTS

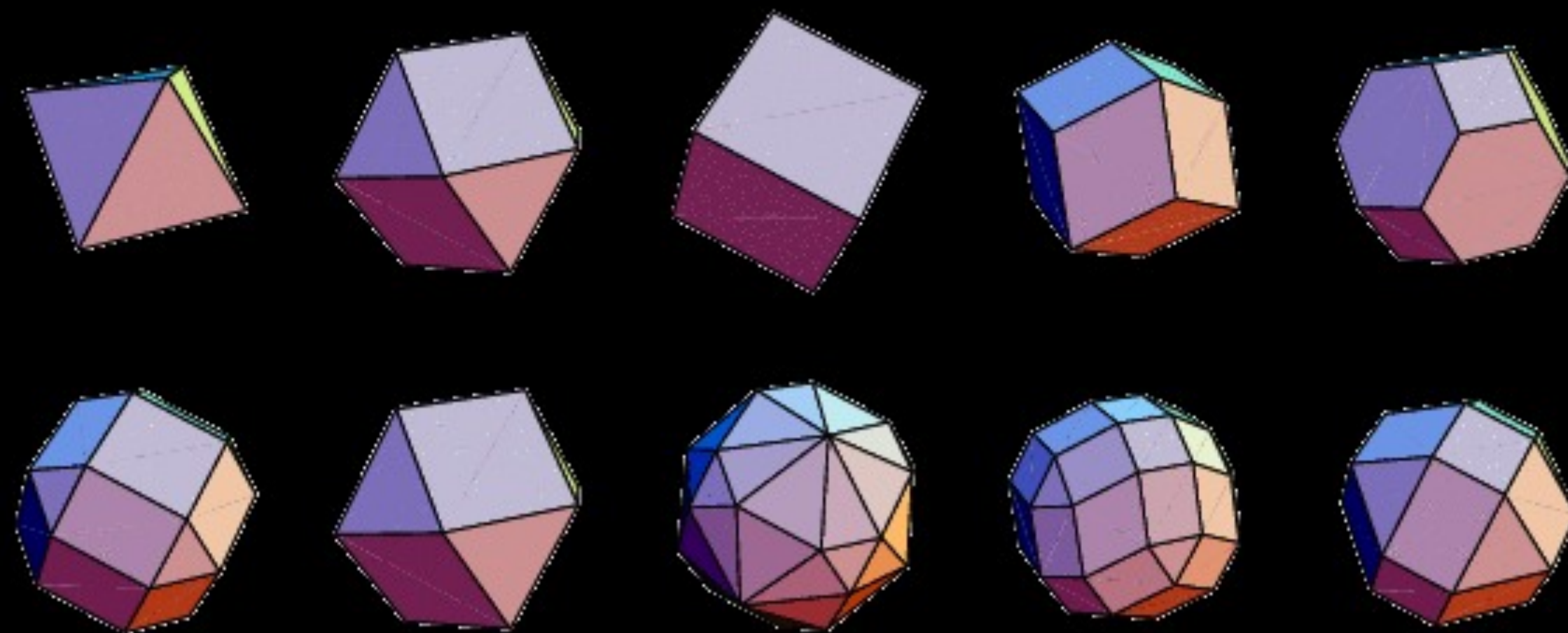
DEFINE SET OF MECHANICAL OPERATORS

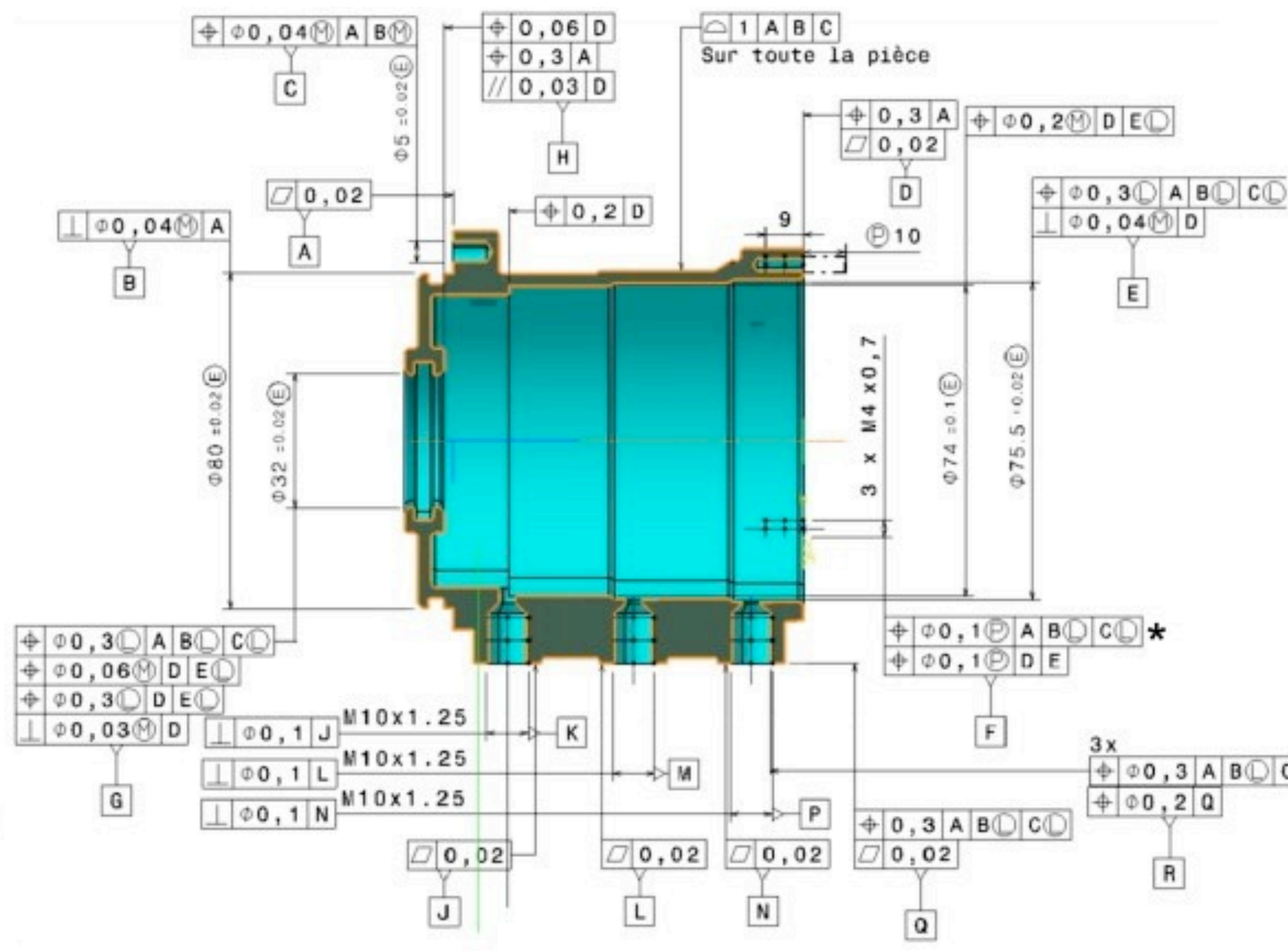
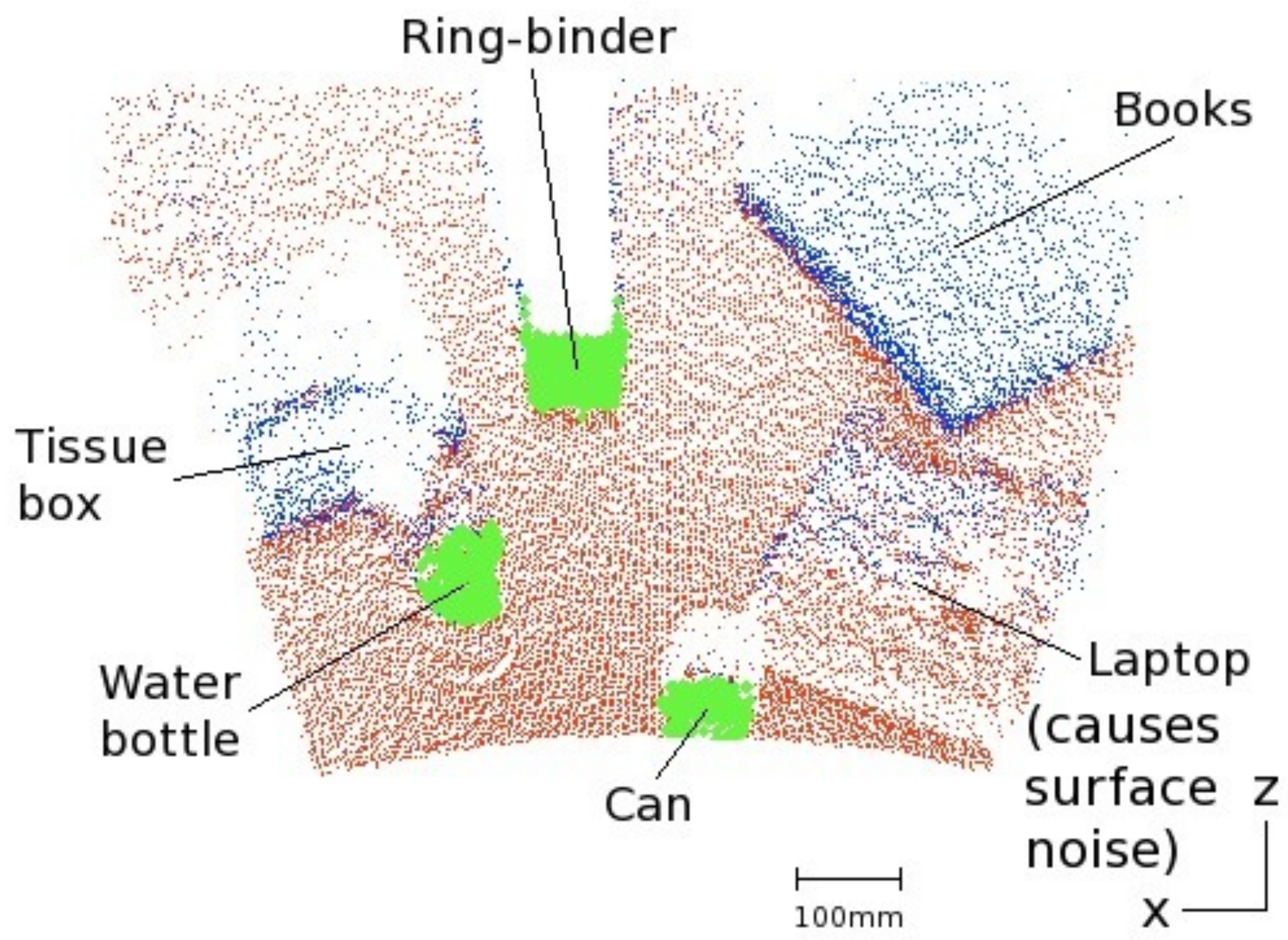
DEFINE SOLUTION(S): CONSTRAINTS, OBJECTIVE (COST)

ALGORITHM OUTPUT: SOLUTION SET (POSSIBLY NULL)

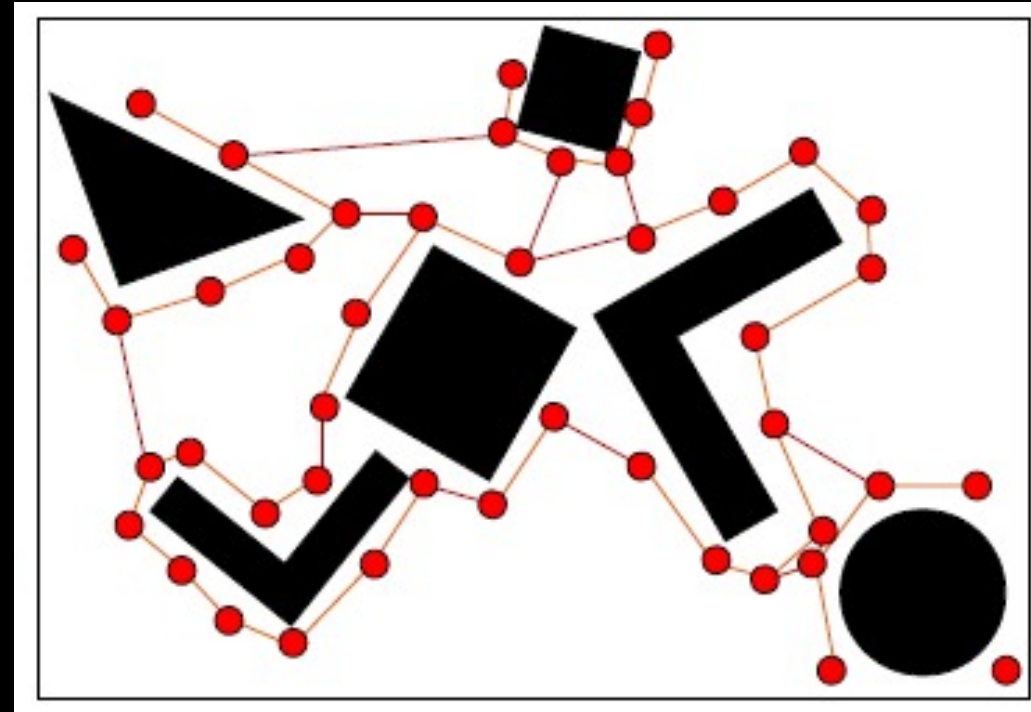
ALGORITHM CORRECTNESS, COMPLETENESS...

ALGORITHM EFFICIENCY AS FUNCTION OF PART COMPLEXITY

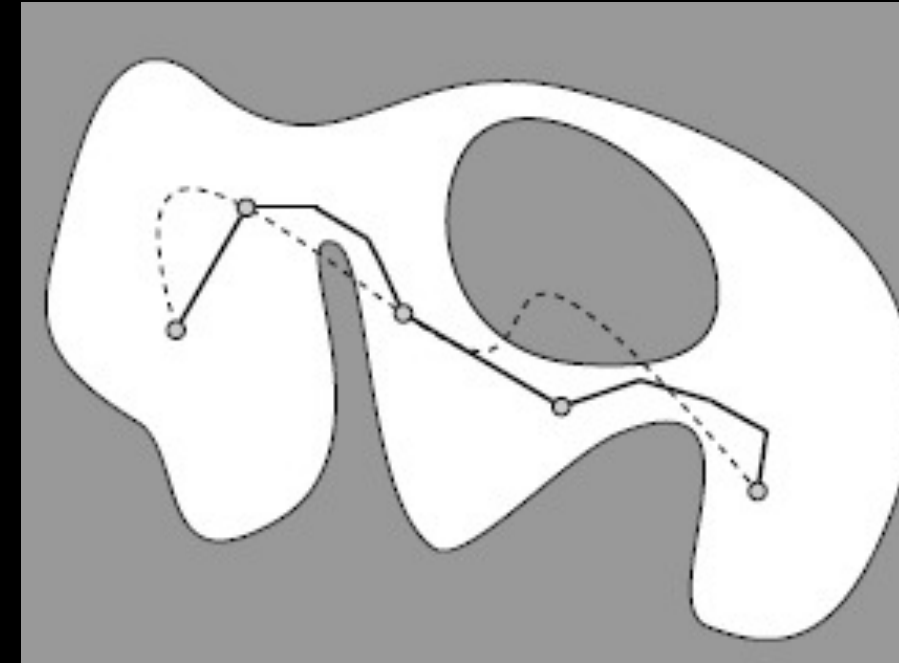




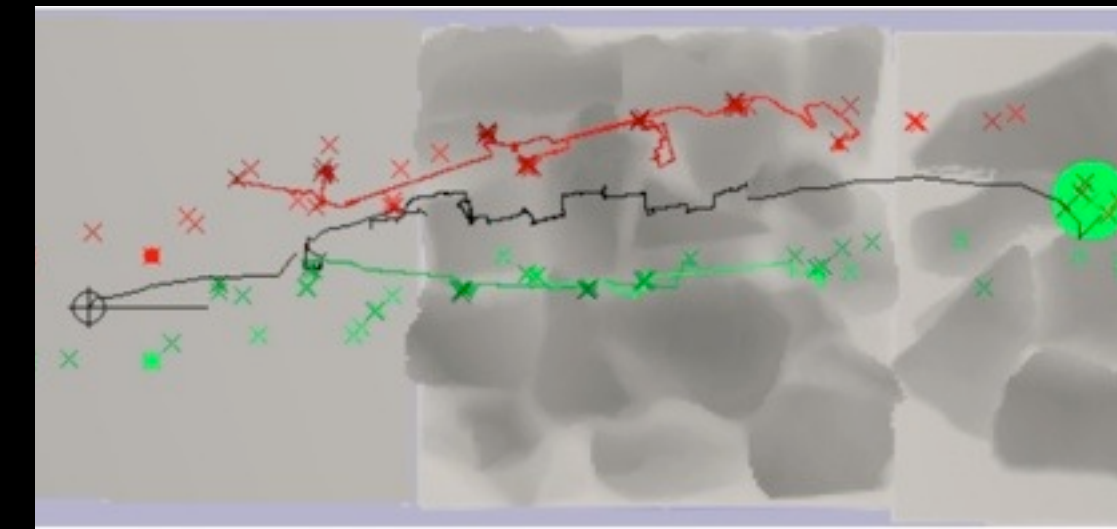
# Related work



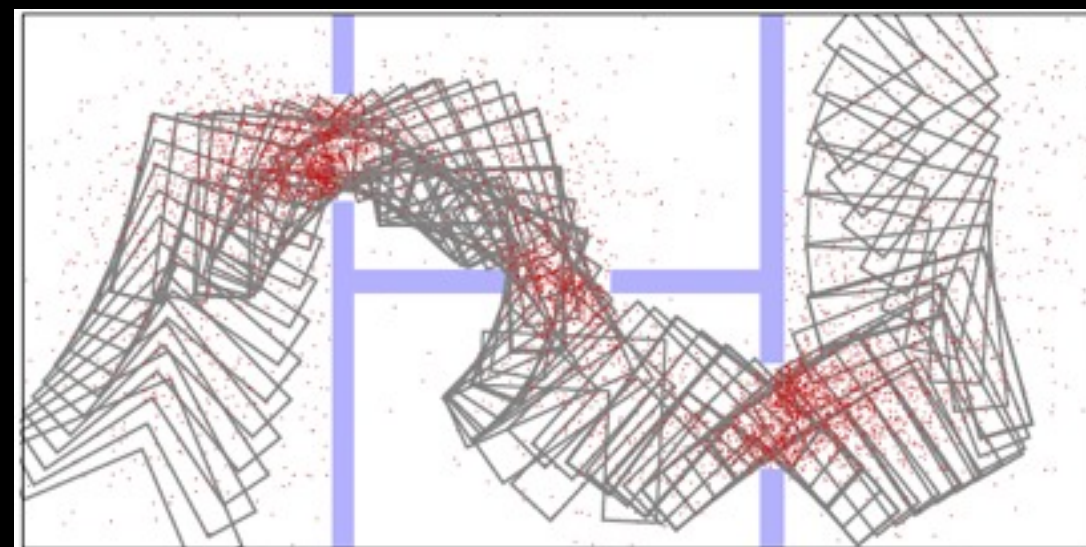
Reuse-PRM based on known obstacles  
Lien and Lu, 2005



Adaptation of Motion Primitives  
Hauser et al, 2006



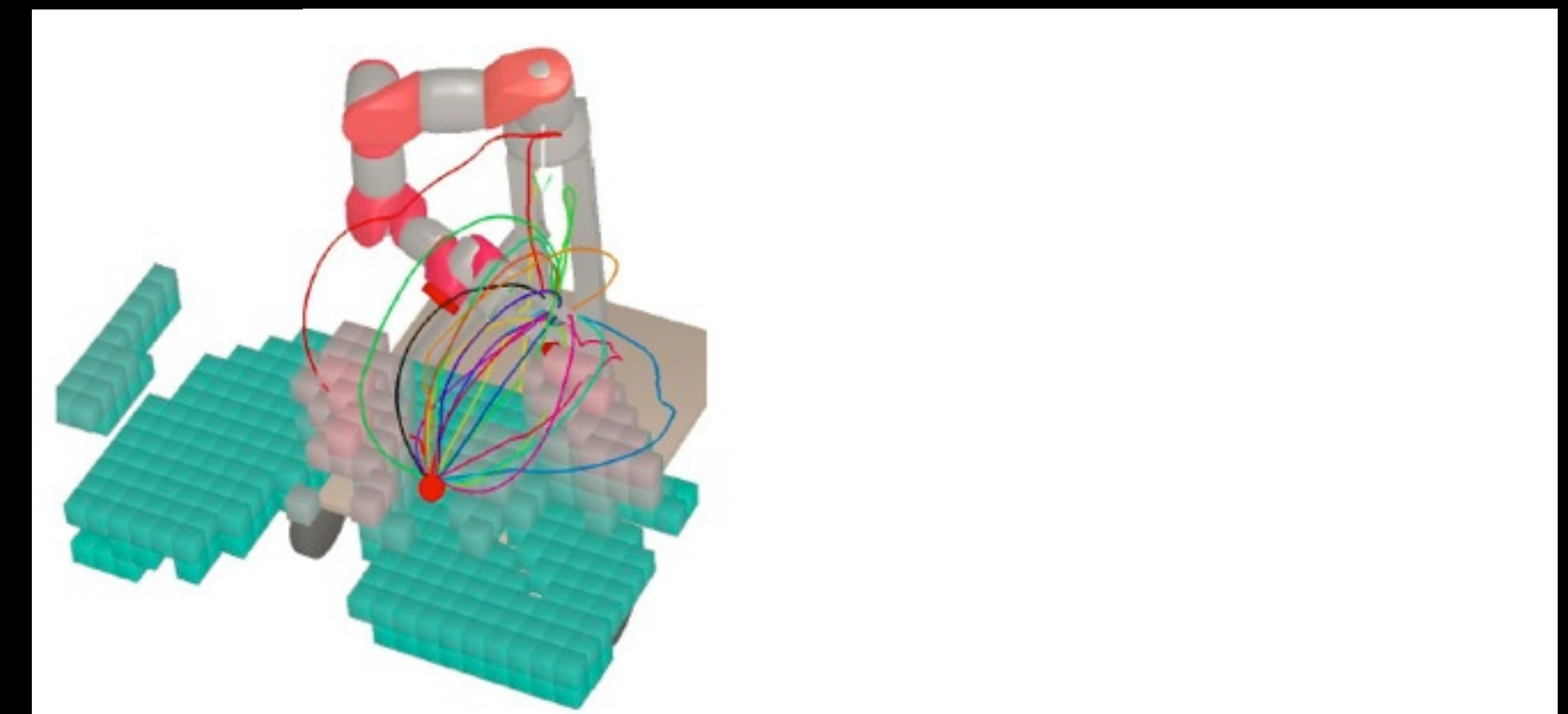
Policy transfer for footstep plans  
Stolle et al, 2007



Learning where to sample  
Zucker et al, 2008



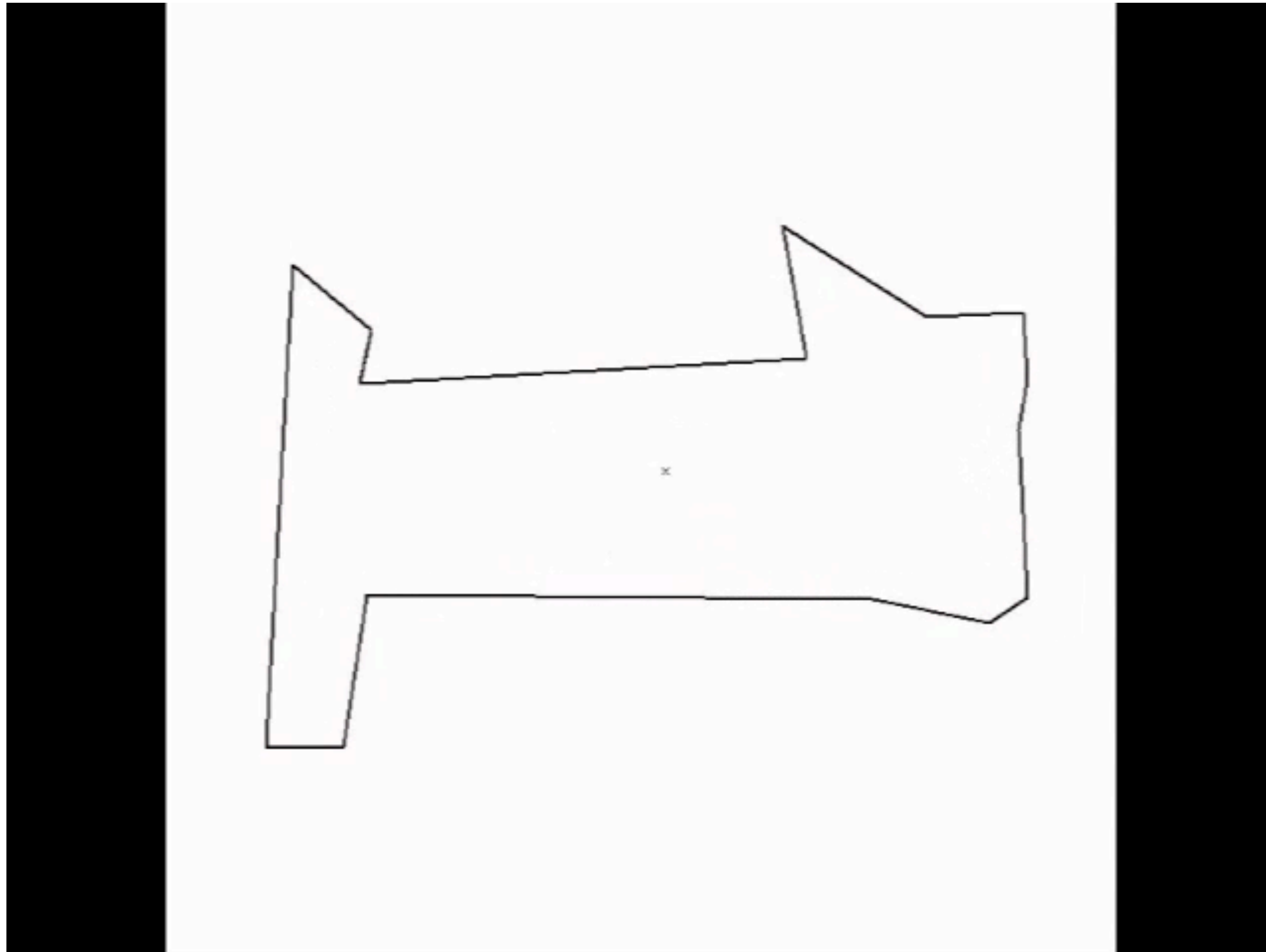
Skill trees from demonstration  
Konidaris, et al, 2010



Path retrieval from static library  
Jetchev and Toussaint, 2010

# Shape Uncertainty

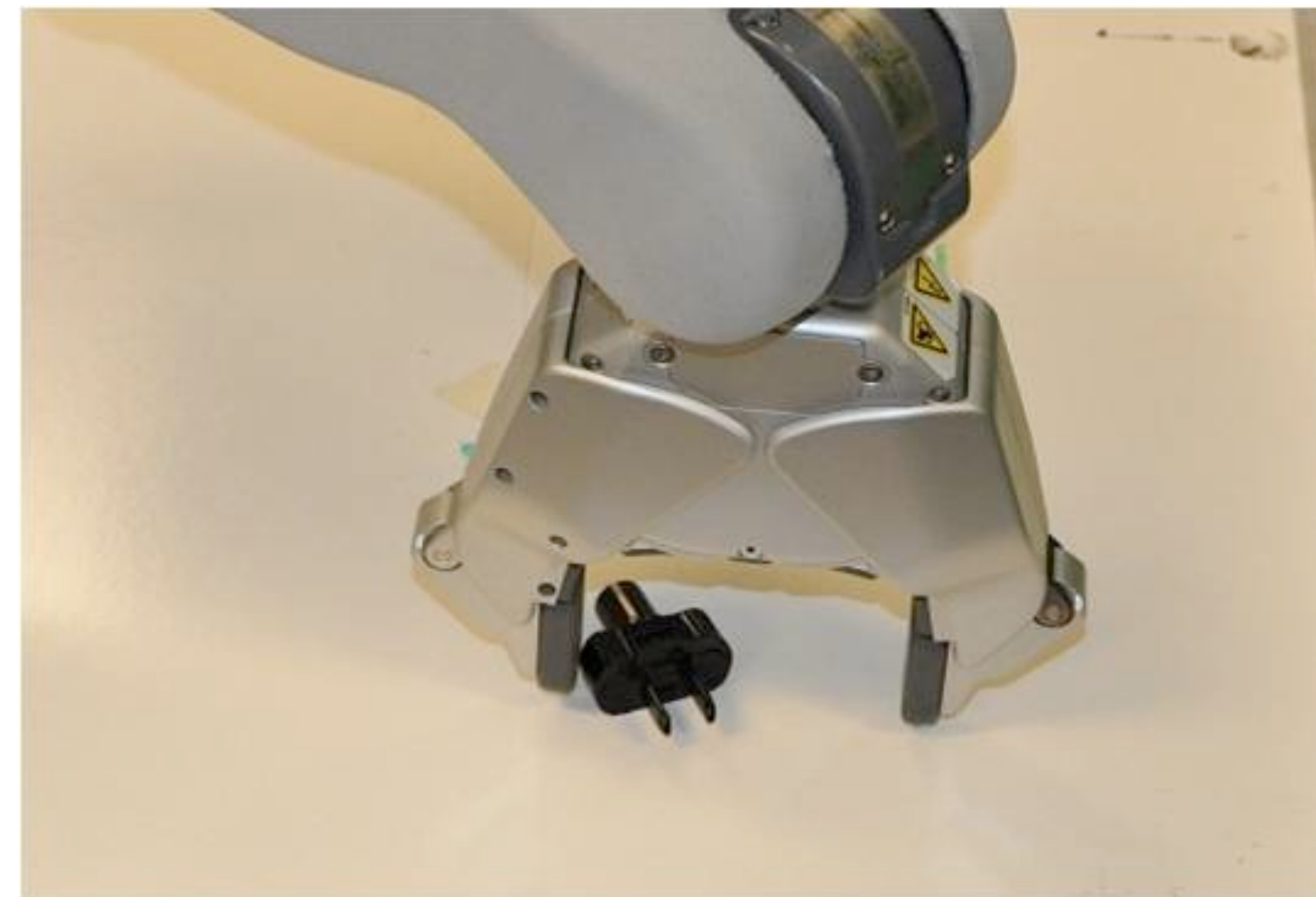
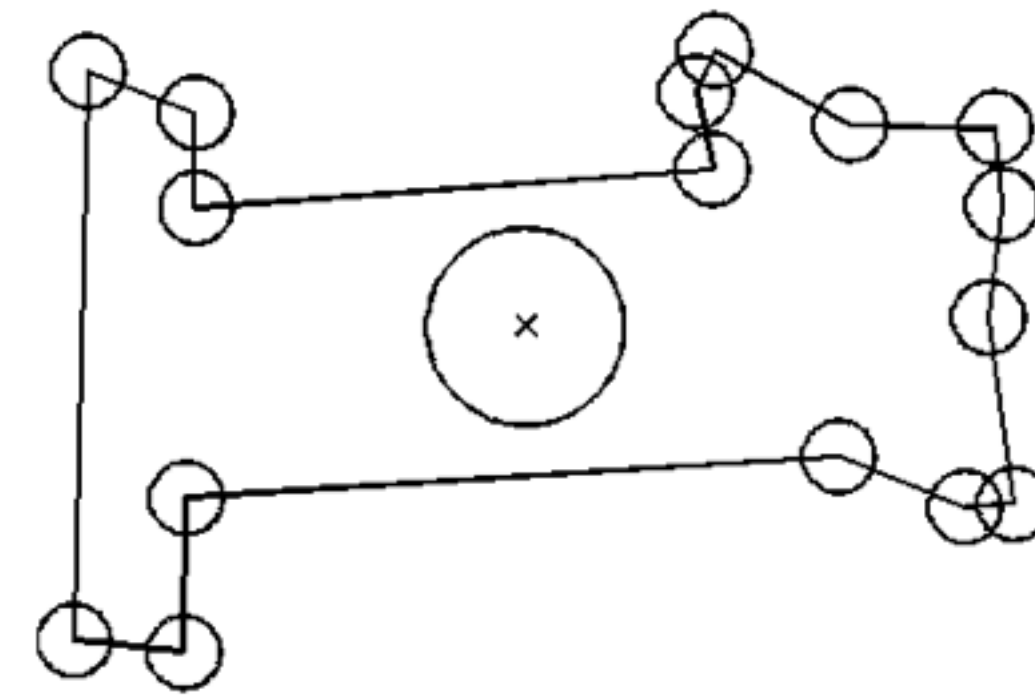
# Shape Uncertainty





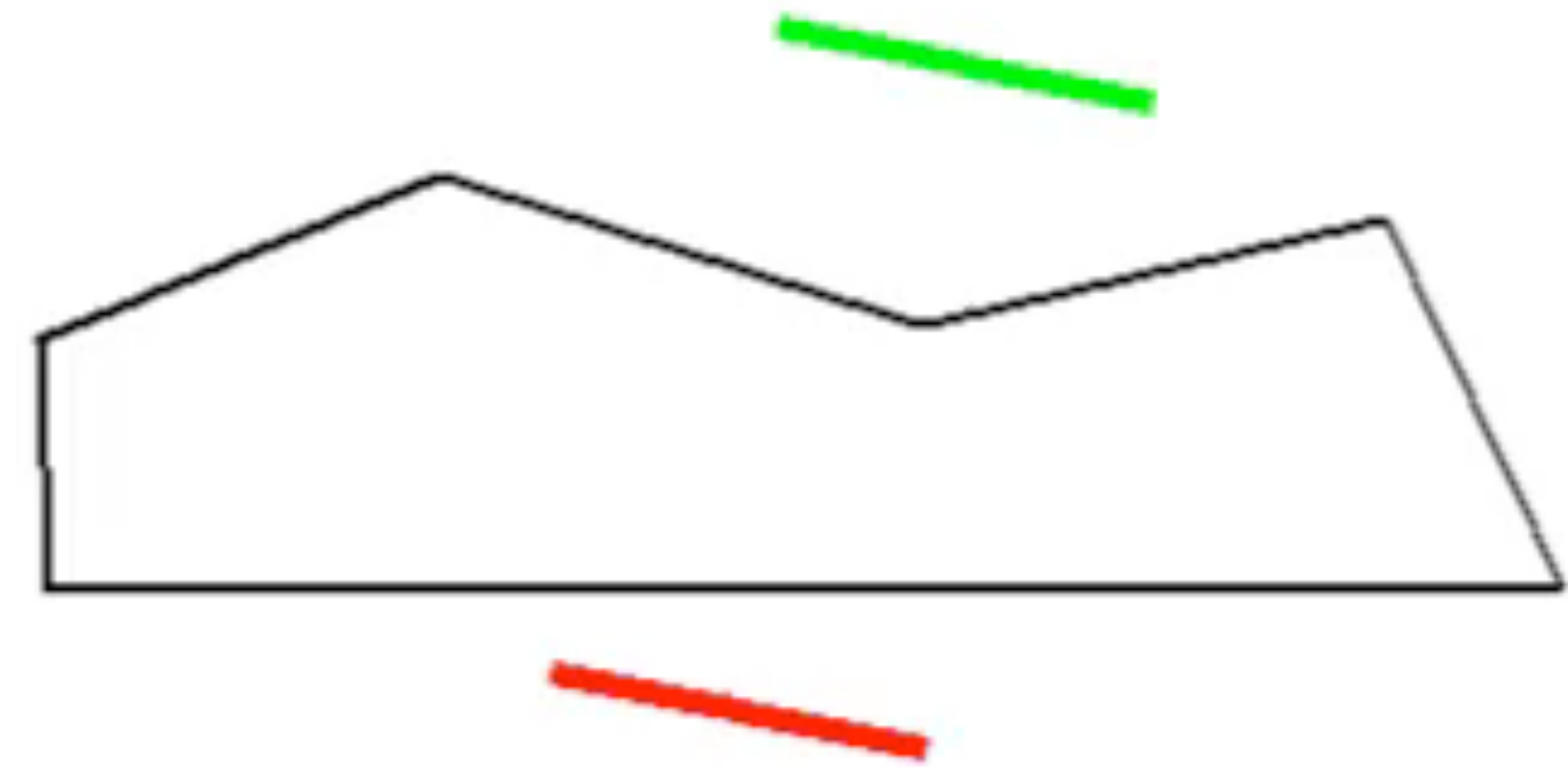
# Problem Statement

- Extruded polygonal object  $S$  on planar work surface
  - Gaussian uncertainty in vertex location and center of mass
  - Quasi-static motion
- Parallel-jaw gripper
  - From above
  - Open loop
  - Conservative estimate of coefficient of friction between gripper and object



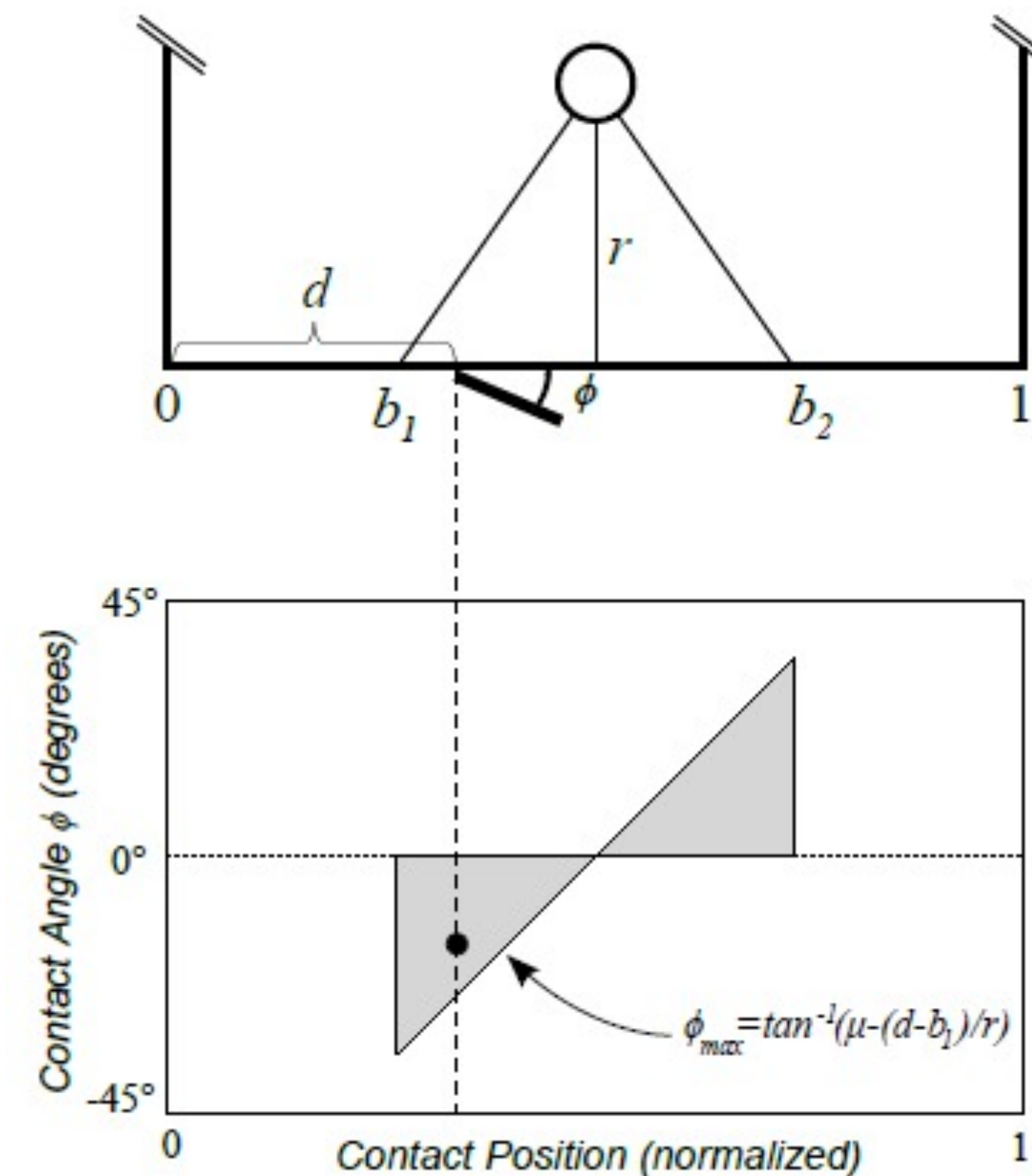
# Zero-Slip Push Grasps with Force Closure

- A class of grasps that enhance object alignment
- Object rotates about the contact point with the gripper (no slipping)
- Object rotates into alignment with the gripper



# Zero-Slip Push Grasps with Force Closure

- Zero-slip pushes can be rapid evaluated without simulation
- Multiple candidate grasps can be evaluated simultaneously
- Force closure tests can have varying levels of conservativeness for speed considerations

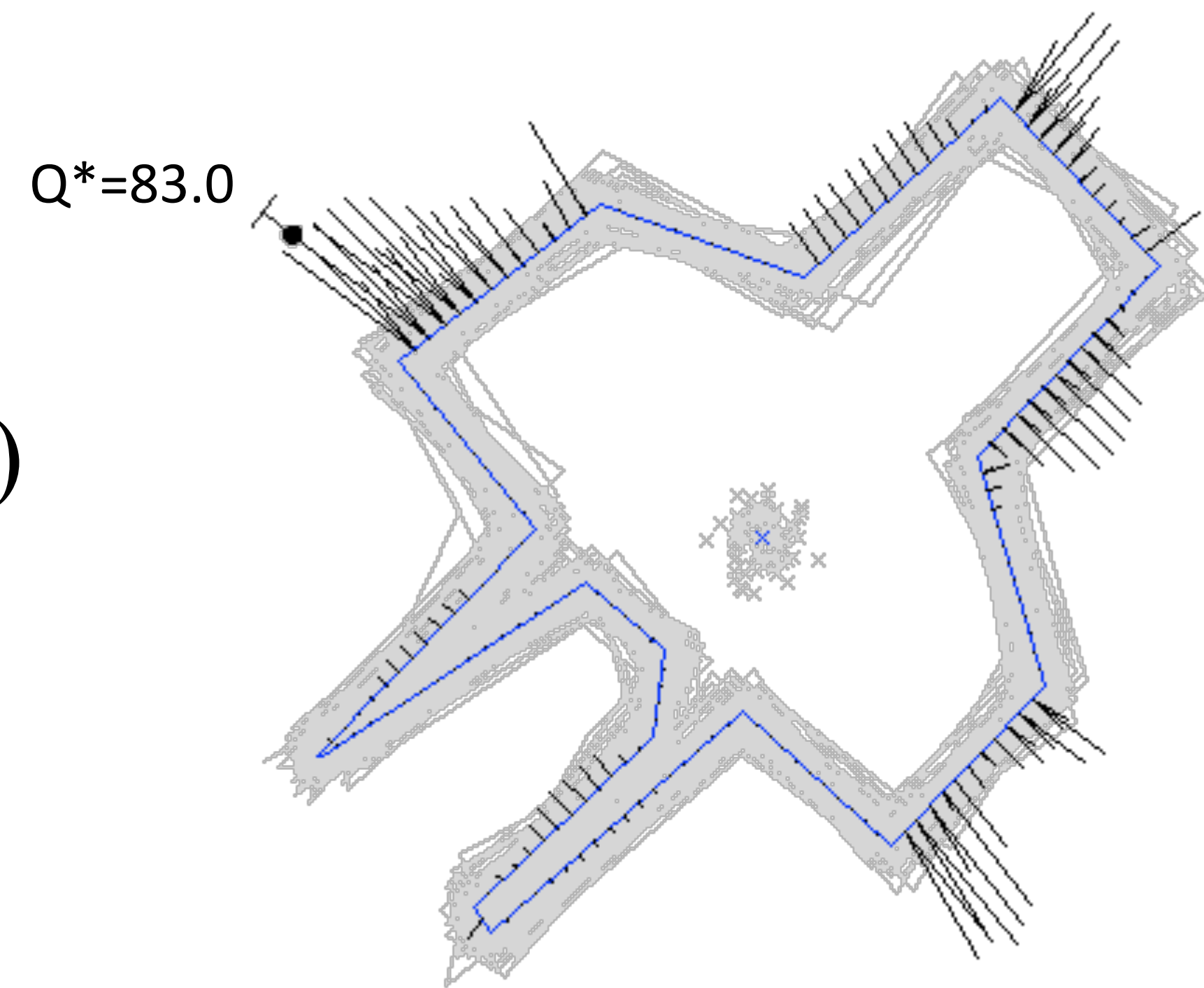


# Quality Measure

- We define a quality measure  $Q(g, S, \theta)$  as a lower bound on the probability of force closure:

$$Q(g, S, \theta) = \sum_{k=1}^N p(S_k) FC(g, S_k, \theta)$$

for grasp  $g$ , parameters  $\theta$ , shape samples  $S_1 \dots S_N$ , and force closure test  $FC$

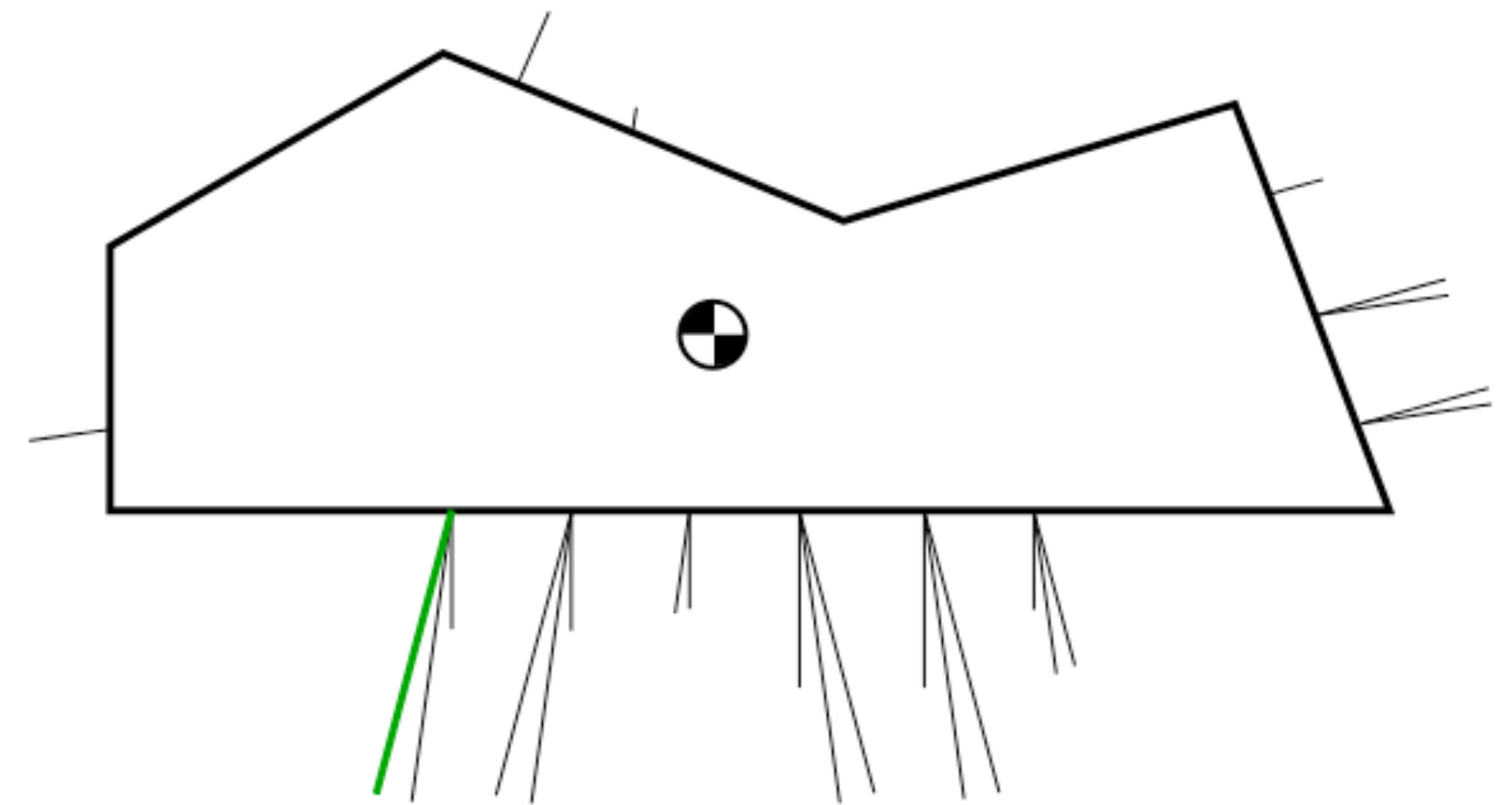
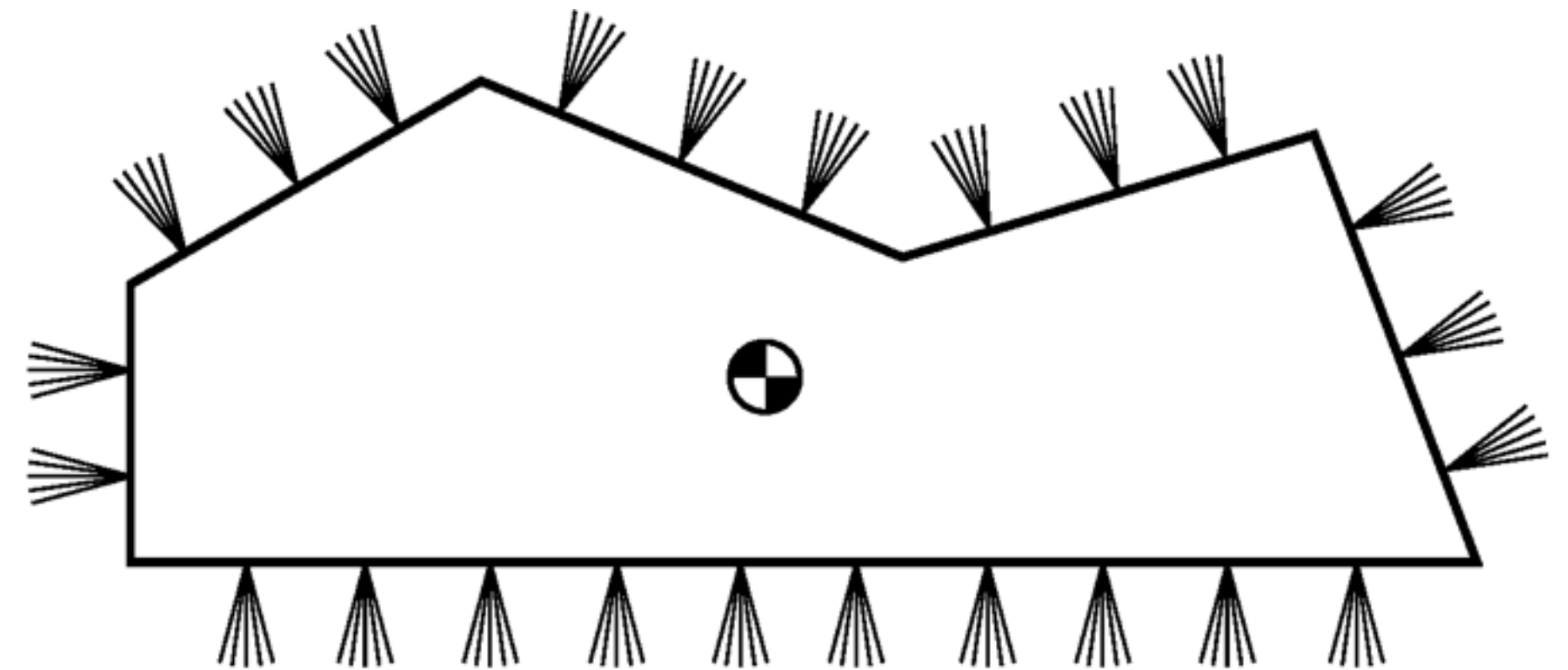


# Quality Measure

- Given a shape  $S$ , candidate grasp set  $G$  and parameters  $\theta$  we want

$$g^*(S, \theta) = \arg \max_{g \in G} Q(g, S, \theta)$$

$$Q^*(S, \theta) = Q(g^*, S, \theta)$$



# Algorithm

Input:

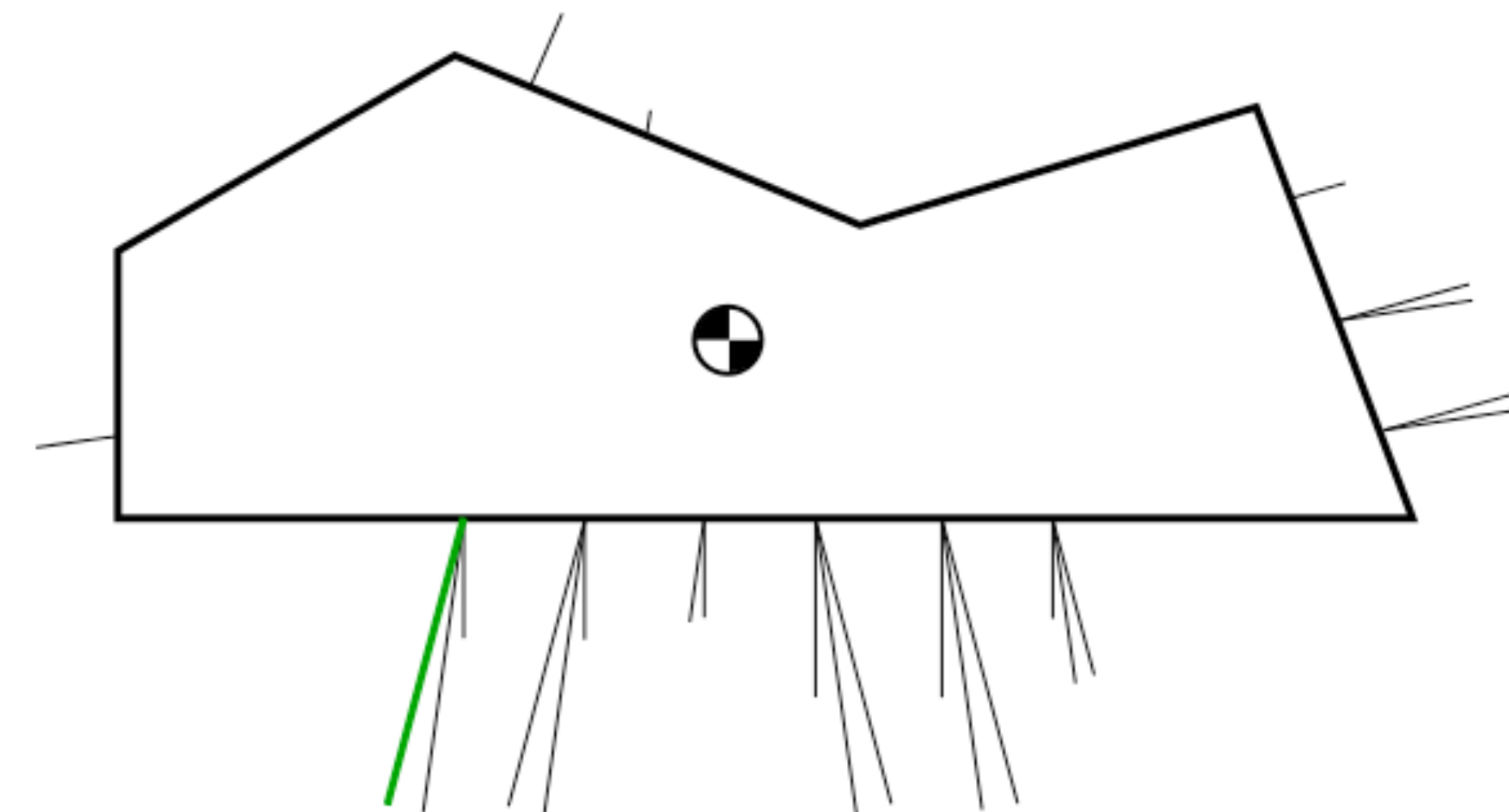
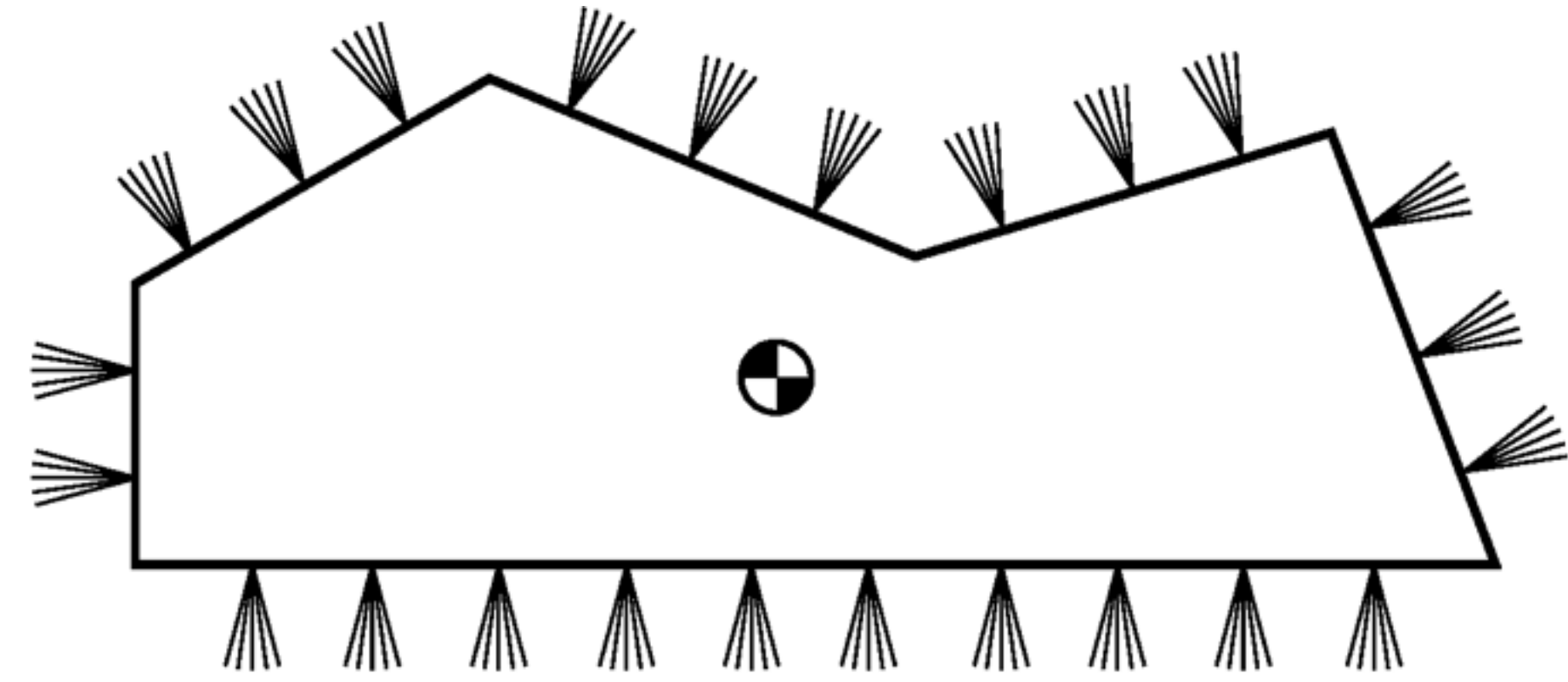
- Nominal object  $S$ 
  - Uncertainty  $\sigma_V$  and  $\sigma_{CM}$
- Candidate grasp set  $G$

Parameters:

- Sample size  $N$
- Gripper dimensions
- Friction  $\mu$

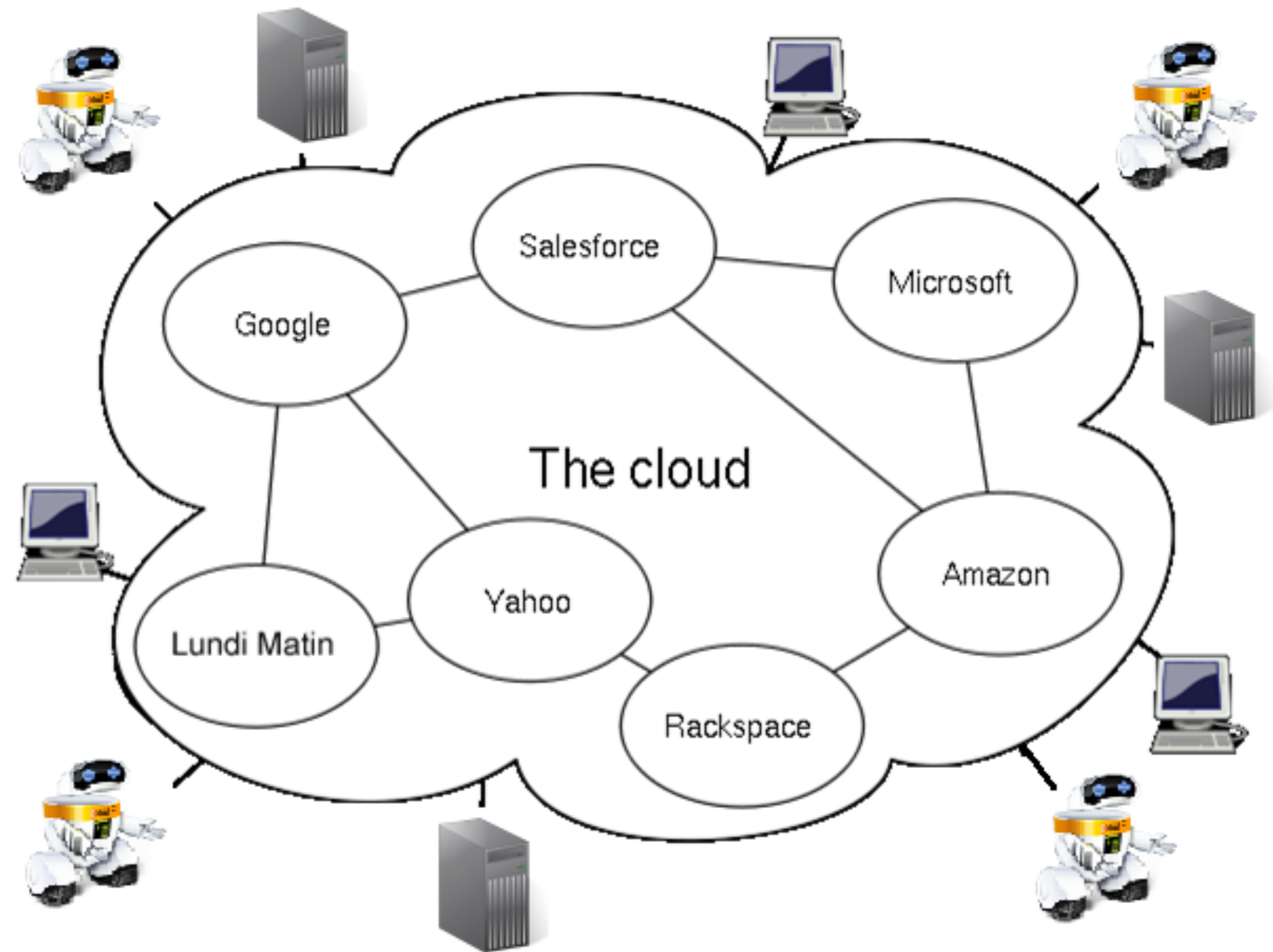
Output:

- For each grasp  $g$  in  $G$ :
  - Quality  $Q(g, S, \theta)$

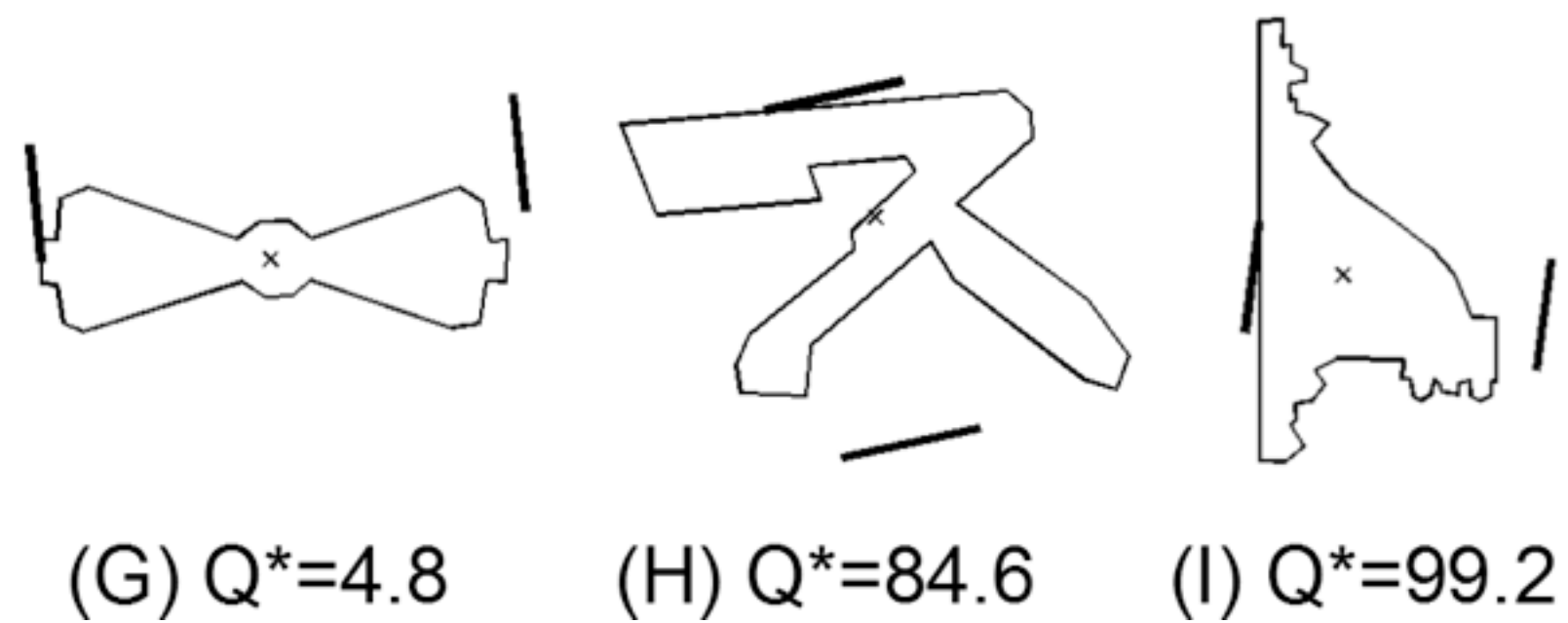
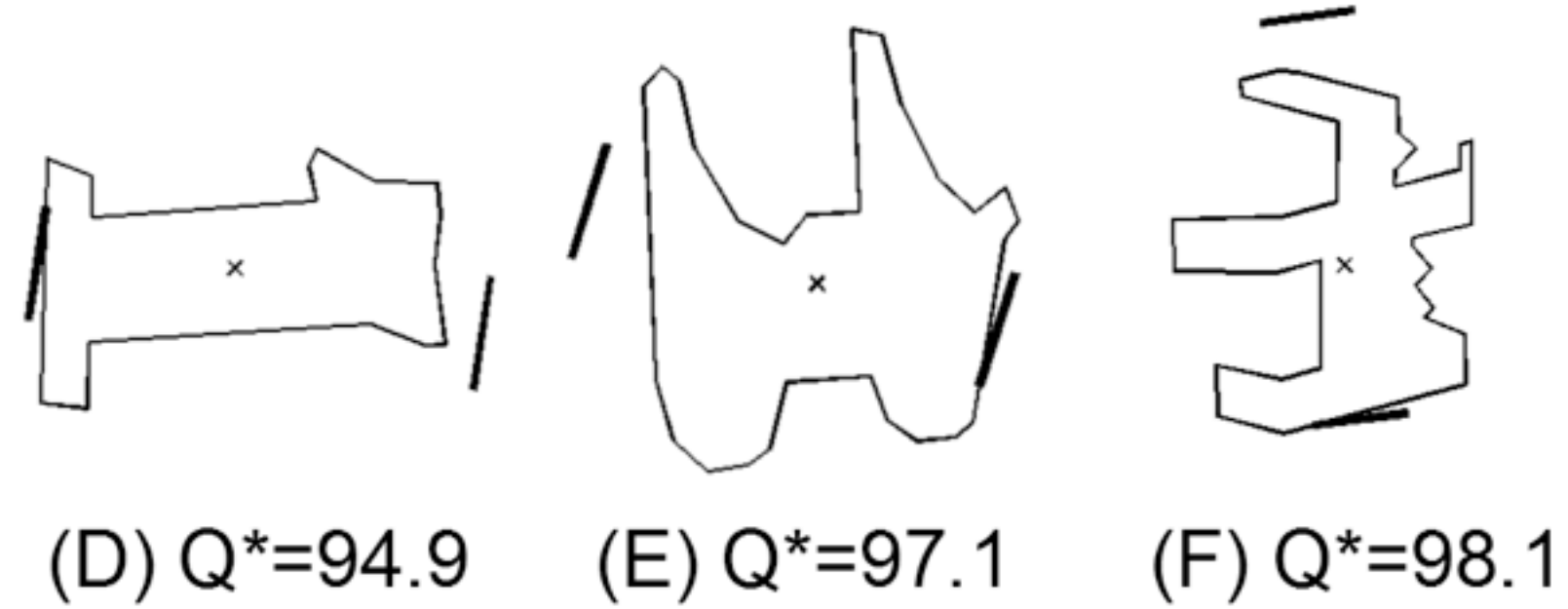
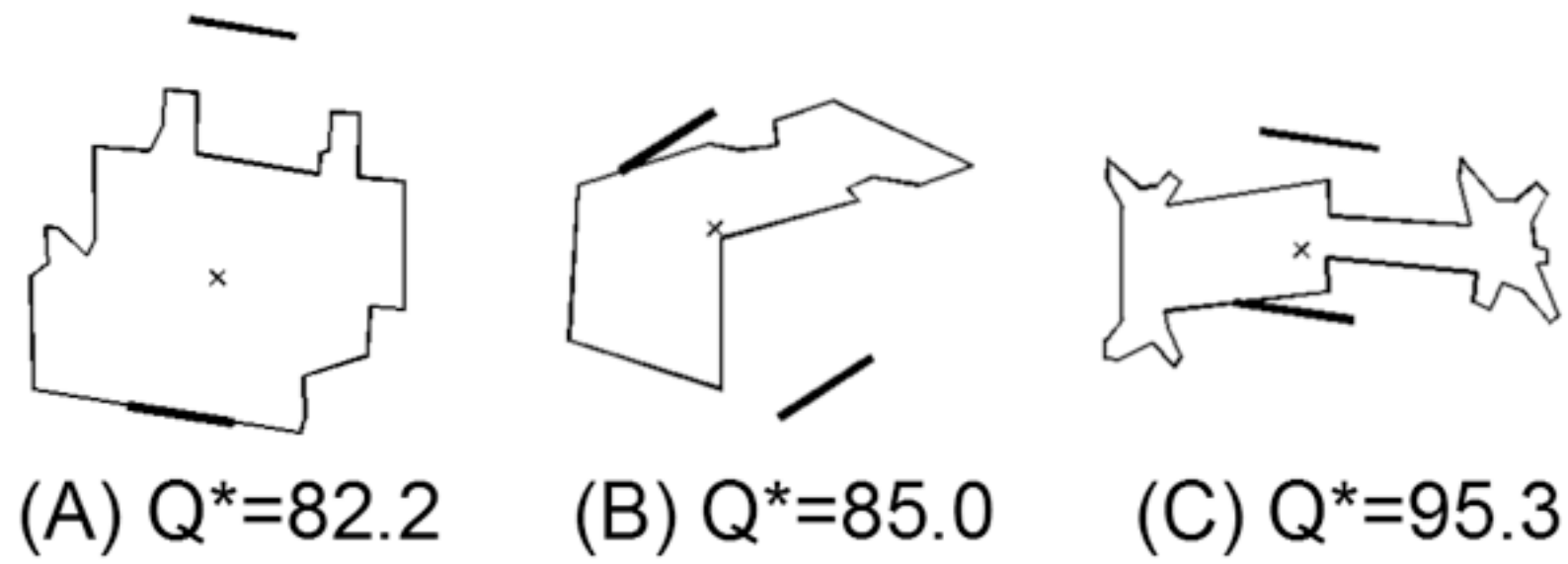


# Algorithm

1. Sample object perturbations
2. **for** *Object perturbation* **do**
3.     Find stable push regions
4.     **for** *Candidate grasp* **do**
5.         Evaluate stable push
6.     Group edge pushes
7.     **for** *Edge push set* **do**
8.         Find force closure regions
9.         **for** *Push configuration* **do**
10.             Evaluate force closure
11.     **for** *Candidate grasp* **do**
12.     Calculate quality



# Results

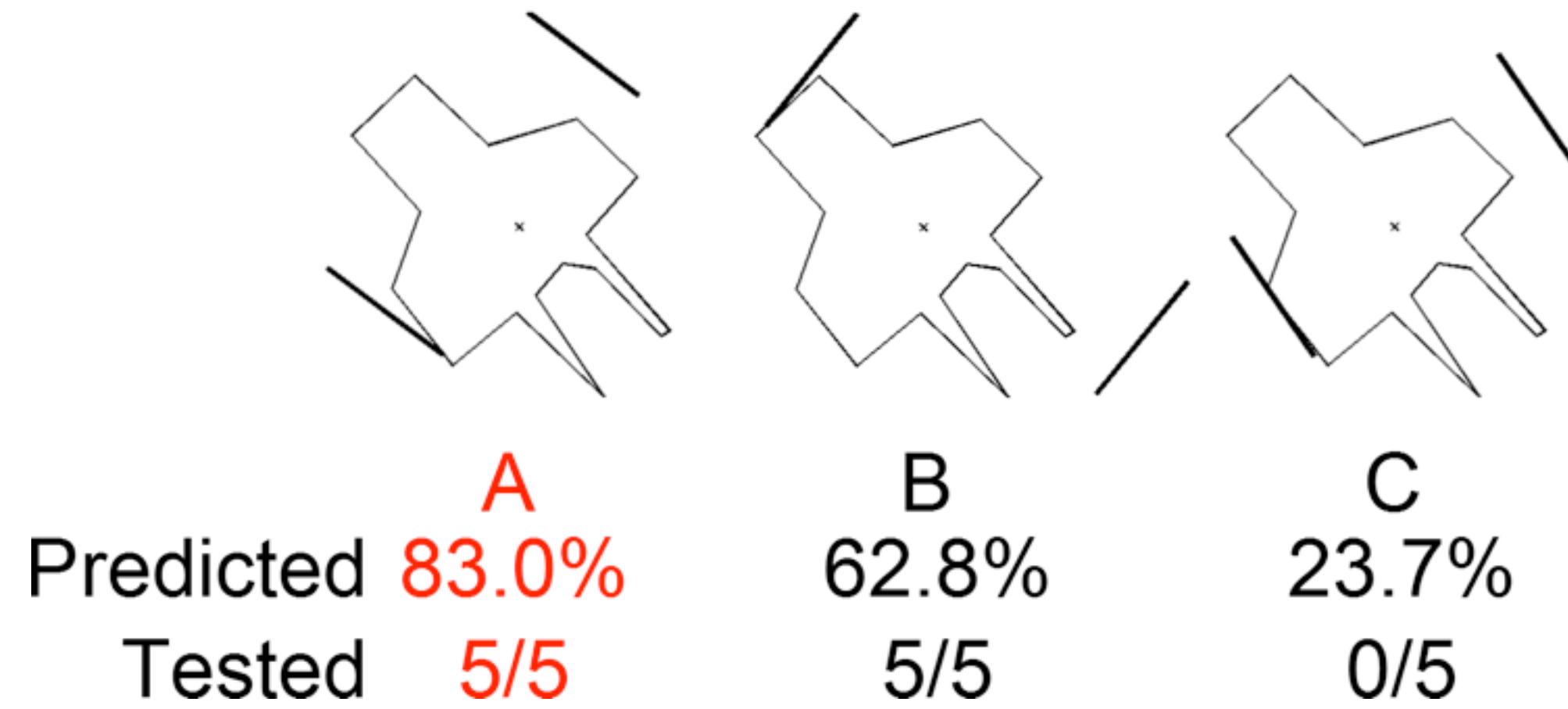
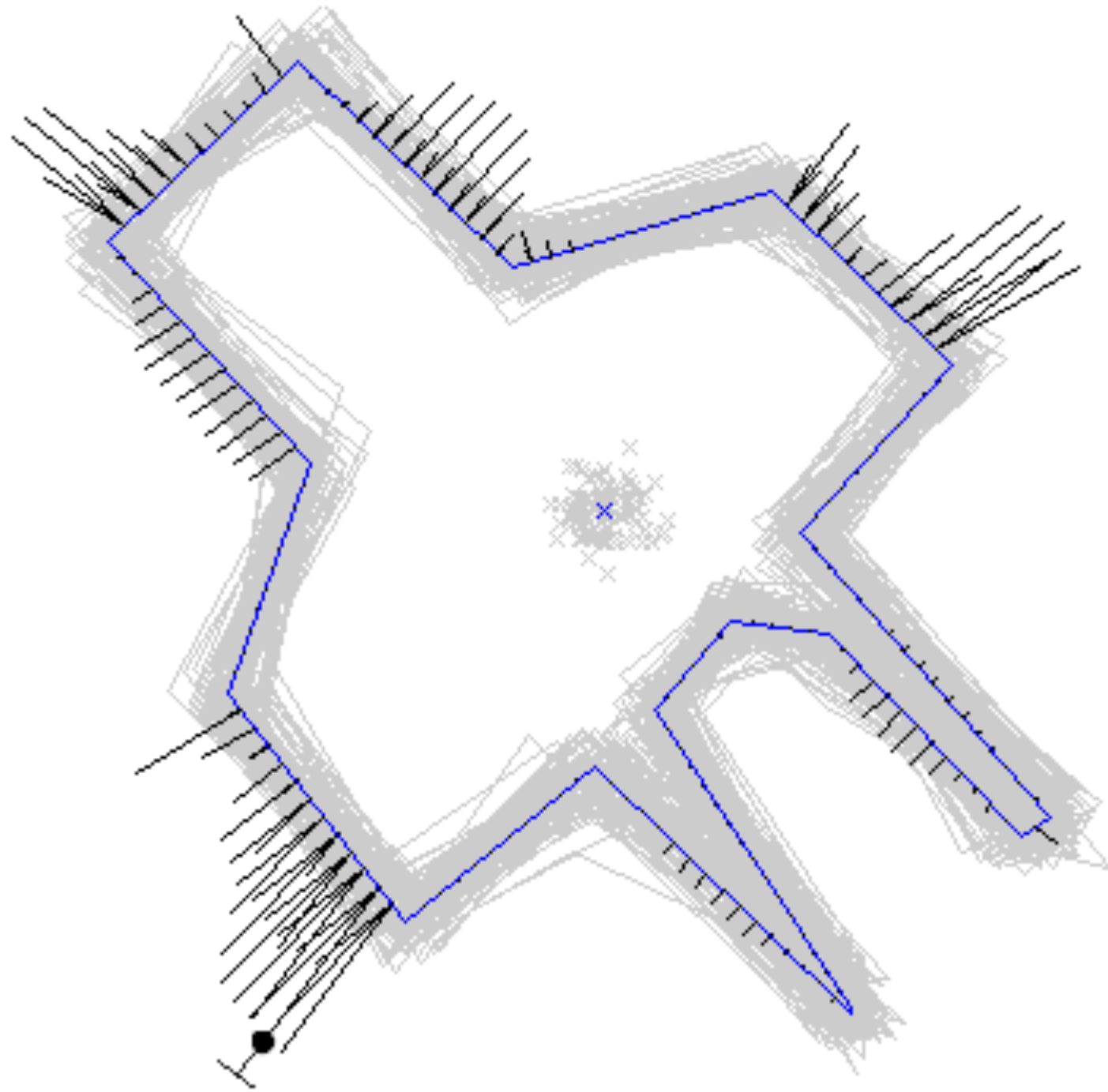


$N = 100$        $\sigma_V = 20\%$  shape radius  
 $\mu = 0.7$        $\sigma_{CM} = 70\%$  shape radius  
 Gripper width = 25% shape diameter

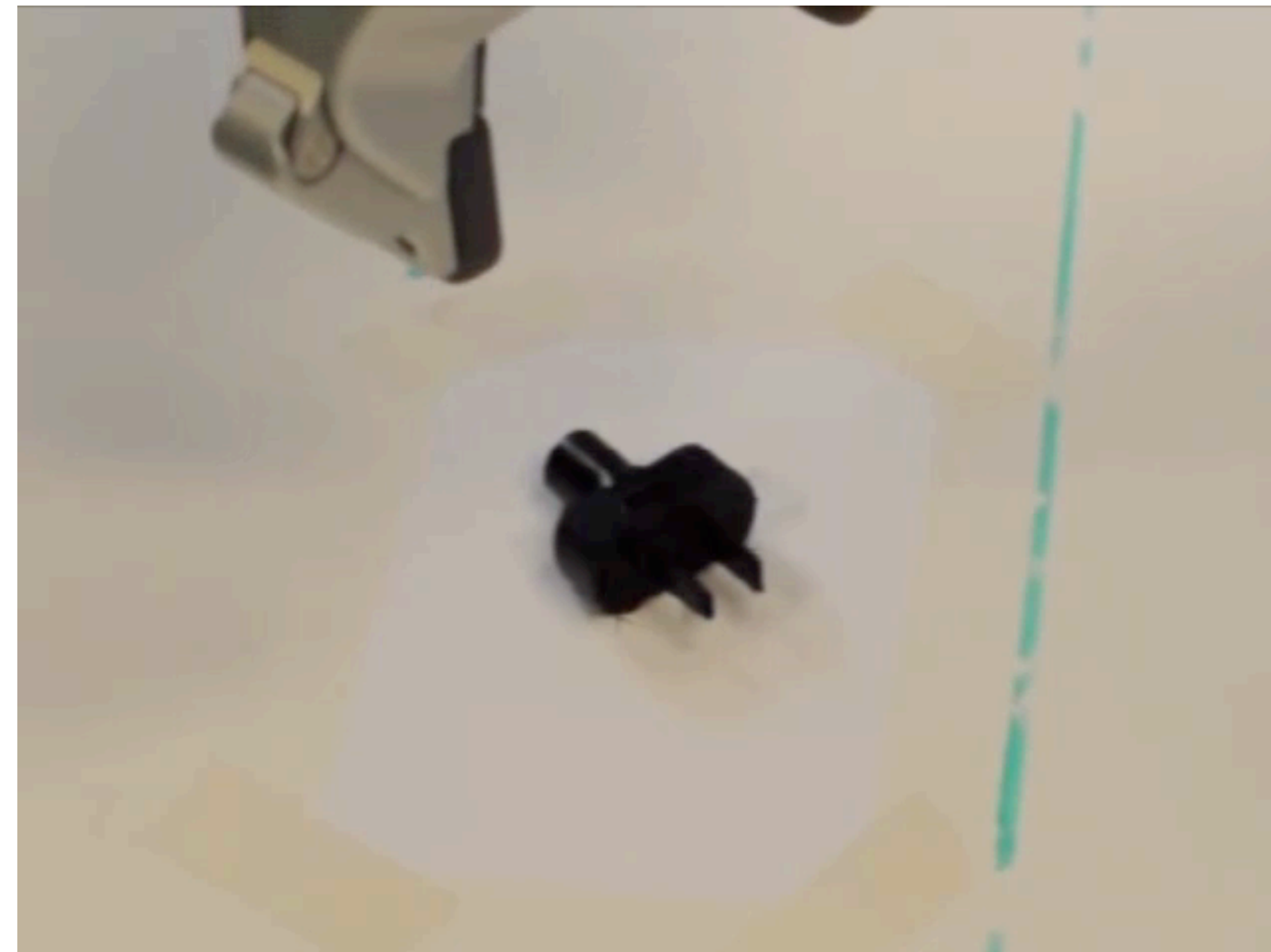
	Time(s)	G	E	t/ G
A	9.44	174	27	0.0543
B	5.79	108	14	0.0536
C	13.14	108	40	0.1217
D	9.11	150	16	0.0608
E	11.73	168	27	0.0698
F	13.38	164	33	0.0816
G	7.78	125	24	0.0623
H	9.58	132	23	0.0726
I	15.35	156	49	0.0984

Parallel speedup:  
 Two core:      1.7x  
 Four core:     3.3x

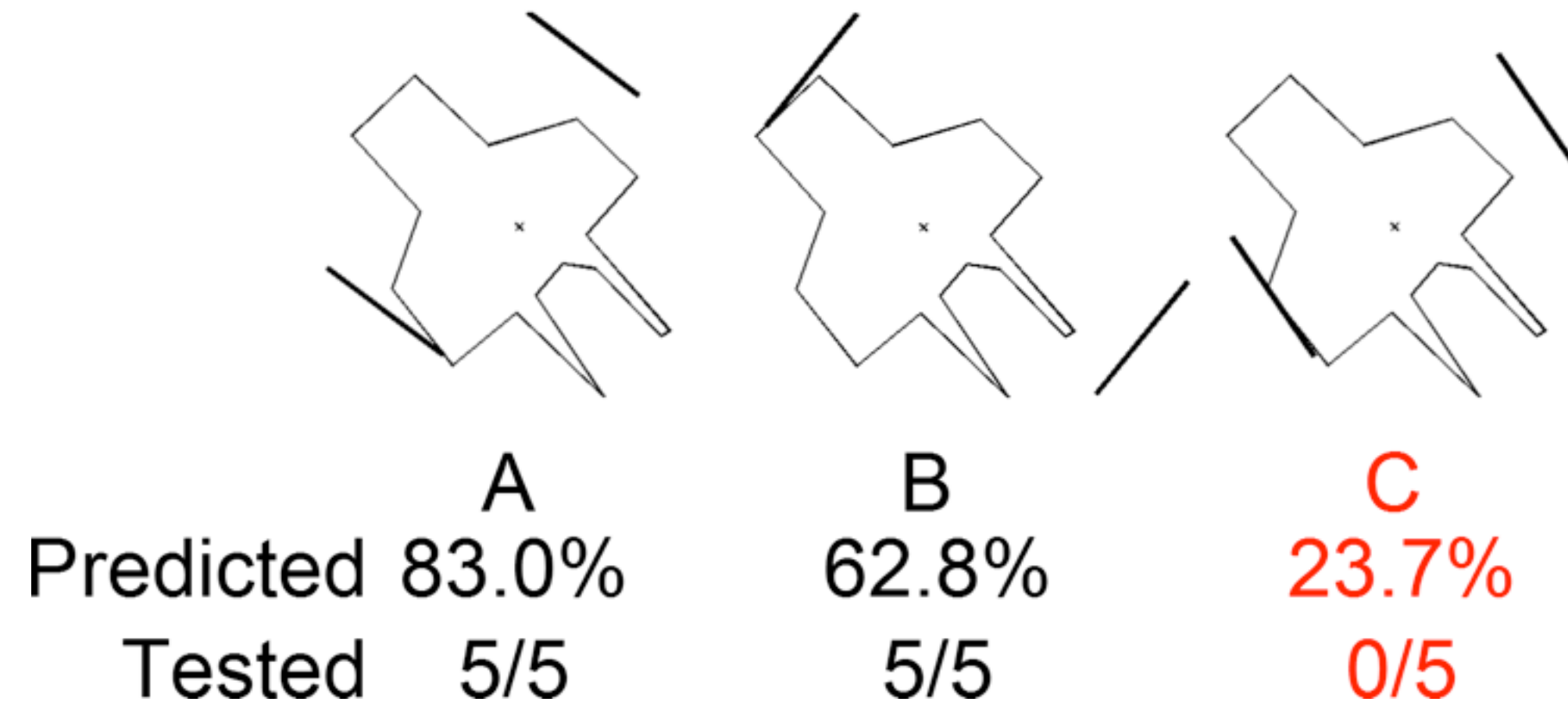
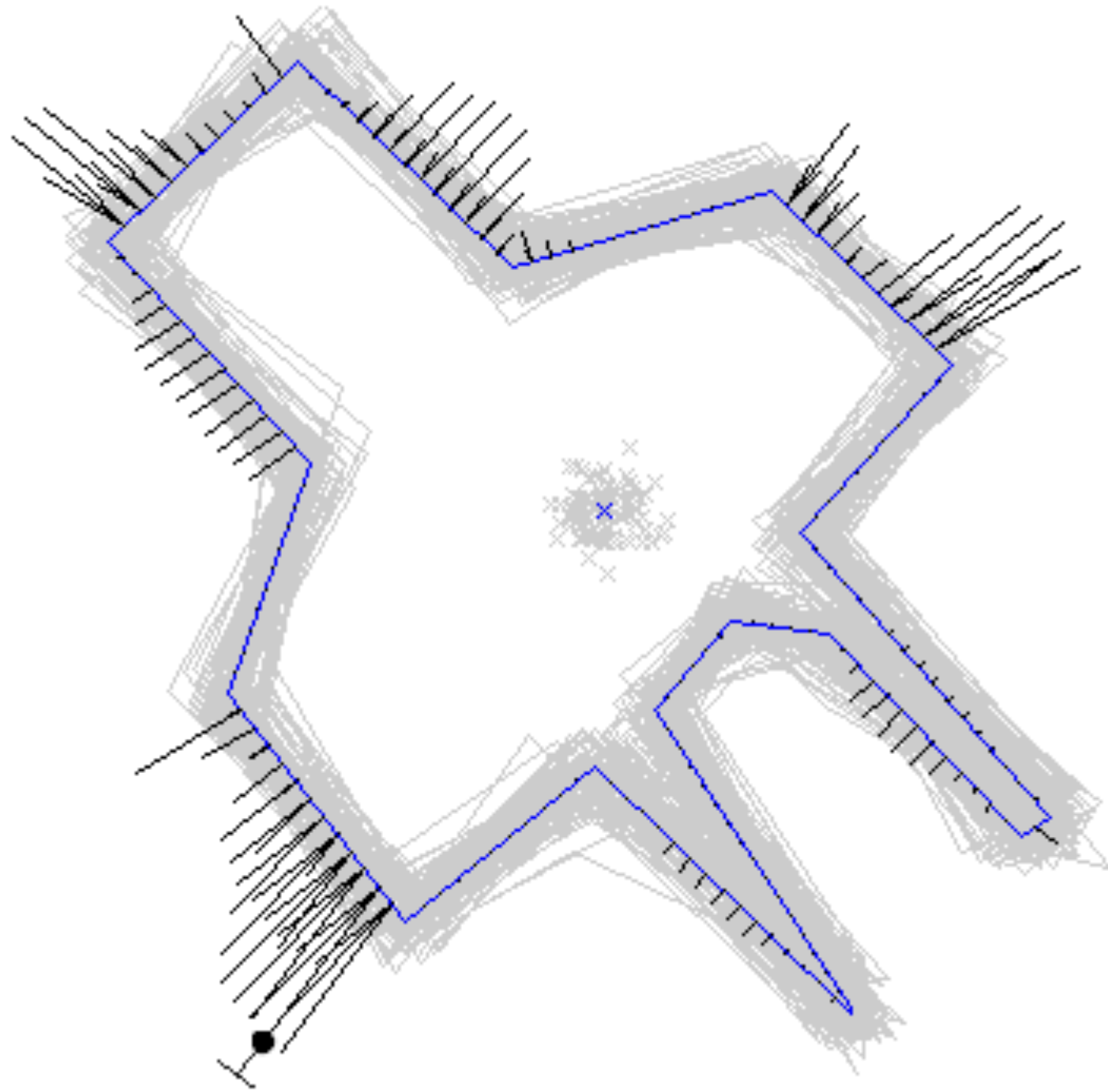
# Results



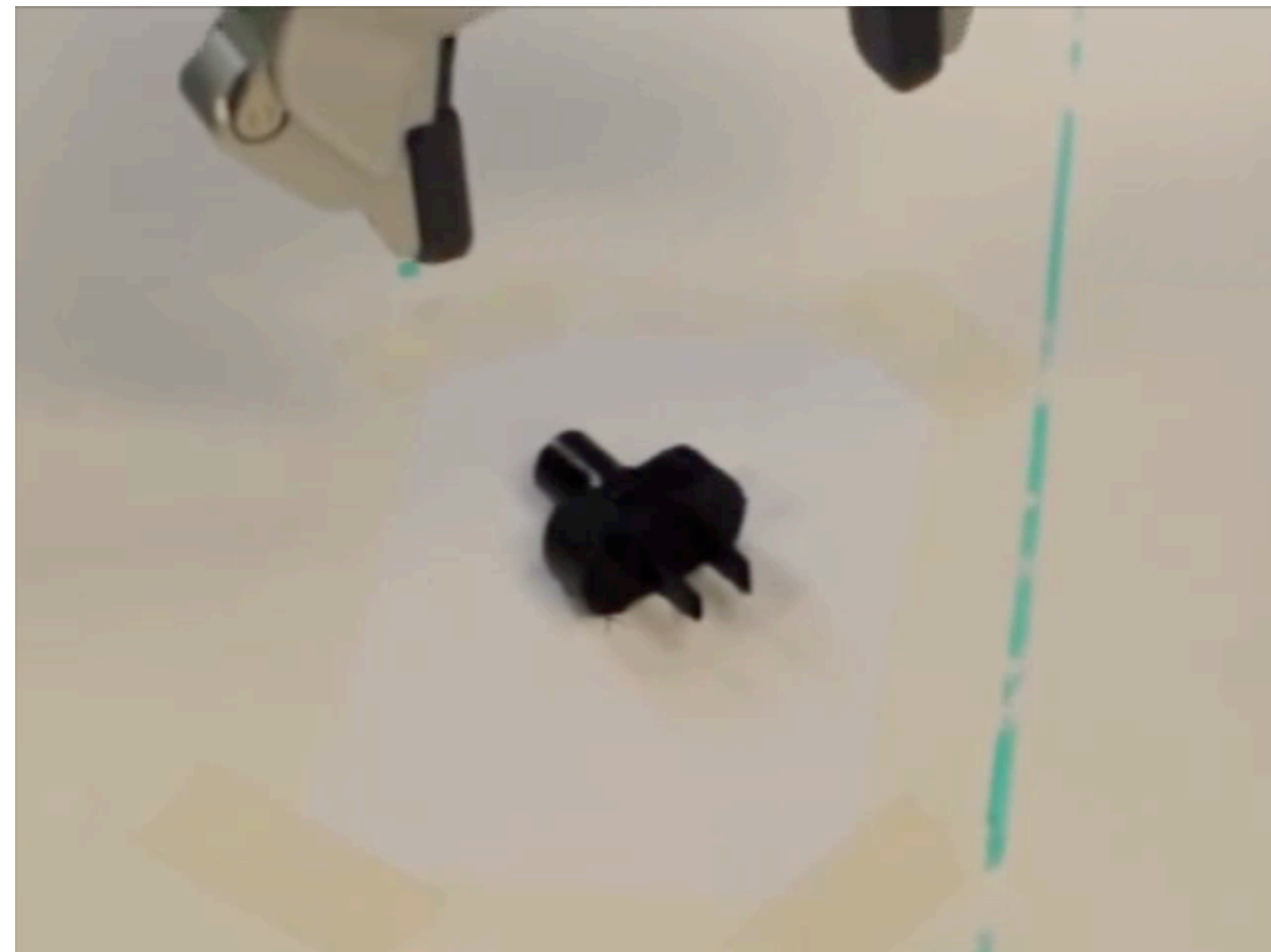
$N = 100$   
 $\mu = 0.7$   
Gripper width = 2.2 cm  
 $\sigma_V = 20\%$  shape radius  
 $\sigma_{CM} = 70\%$  shape radius



# Results



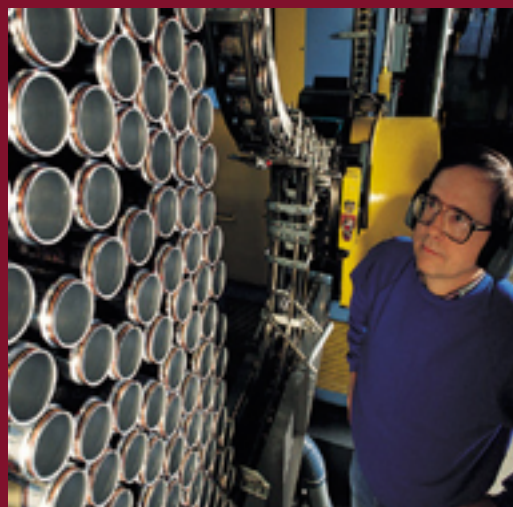
$N = 100$   
 $\mu = 0.7$   
Gripper width = 2.2 cm  
 $\sigma_V = 20\%$  shape radius  
 $\sigma_{CM} = 70\%$  shape radius



Google™

  
CISCO

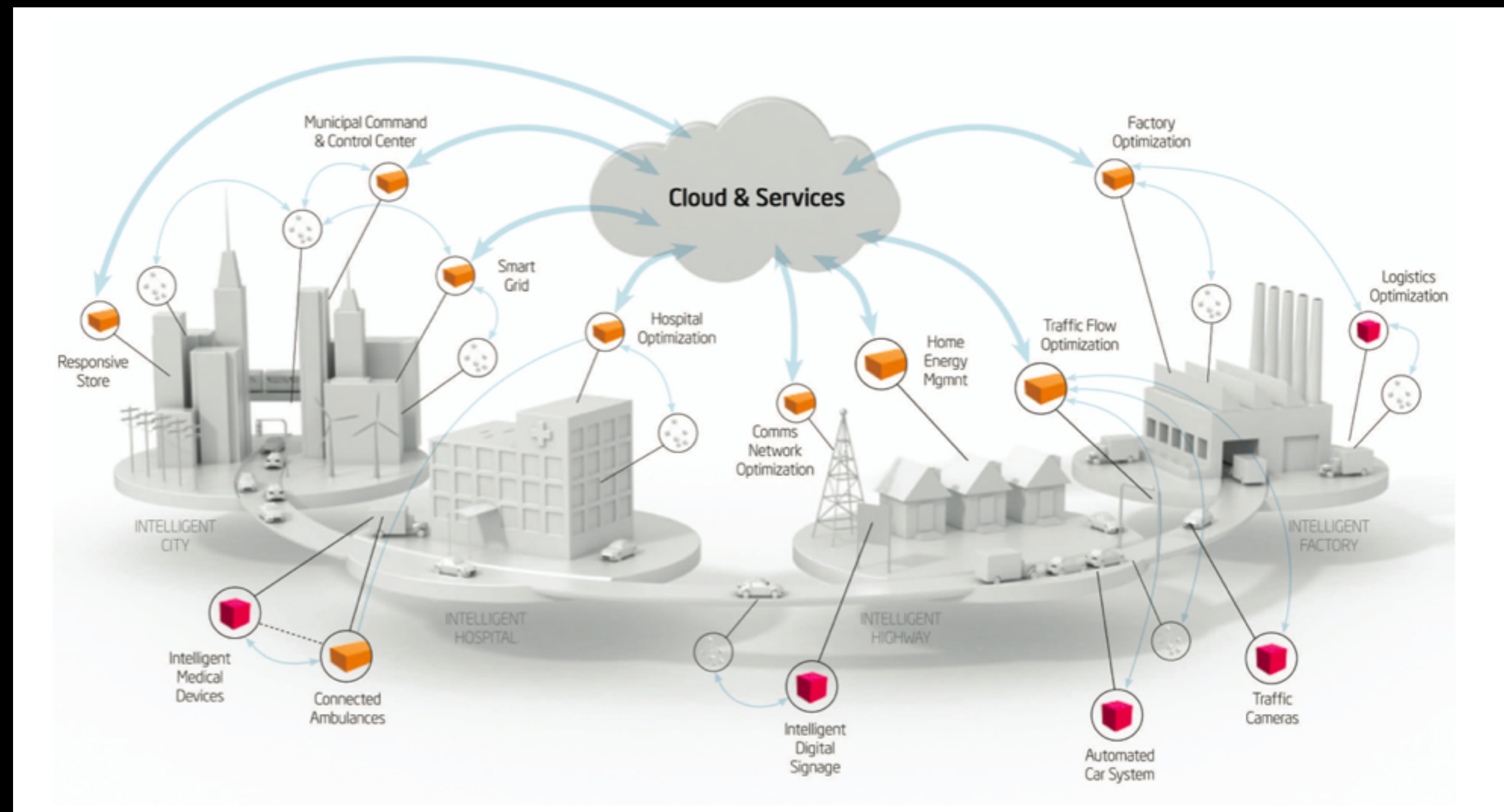
# IEEE TRANSACTIONS ON **AUTOMATION SCIENCE AND ENGINEERING**



Automation plays an increasingly important role in the global economy and in our daily lives. Automation is changing manufacturing as well as healthcare, security, and energy. T-ASE publishes new abstractions, algorithms, theory, methodologies, models, systems, and case studies that can be applied across industries to significantly advance efficiency, quality, productivity, and reliability for society.

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# IEEE/NSF WORKSHOP ON CLOUD MFG AND AUTOMATION



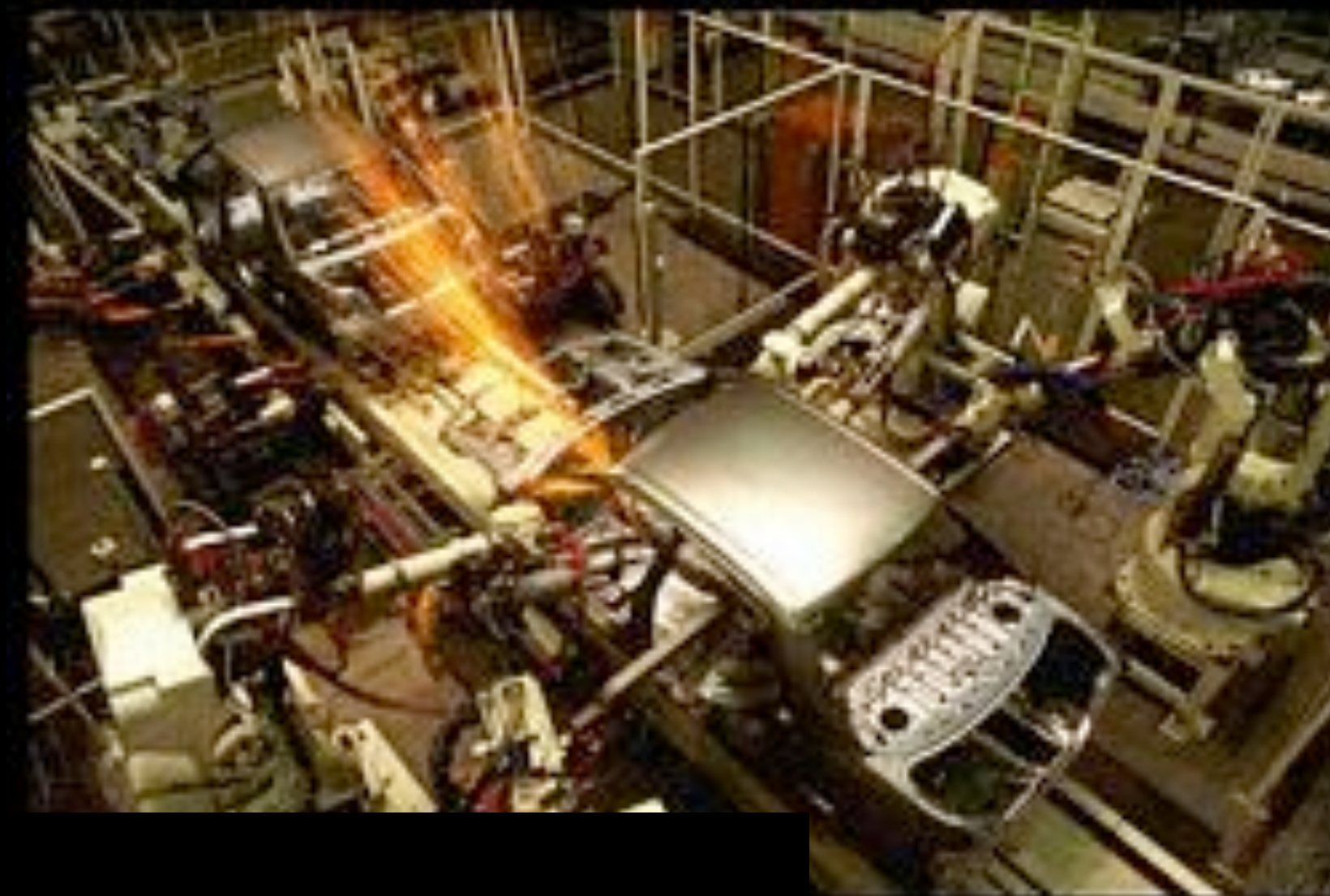
DEZHEN SONG, KEN GOLDBERG, ANI HSIEH

# Robotics v. Automation

- Both involve: computers, physical world, geometry
- Both engage many disciplines
- “robota” coined in 1920 (Capek)
  - Emphasizes feasibility
- “automation” coined in 1948 (Ford Motors)
  - Emphasizes optimality, consistency, guarantees



robotics



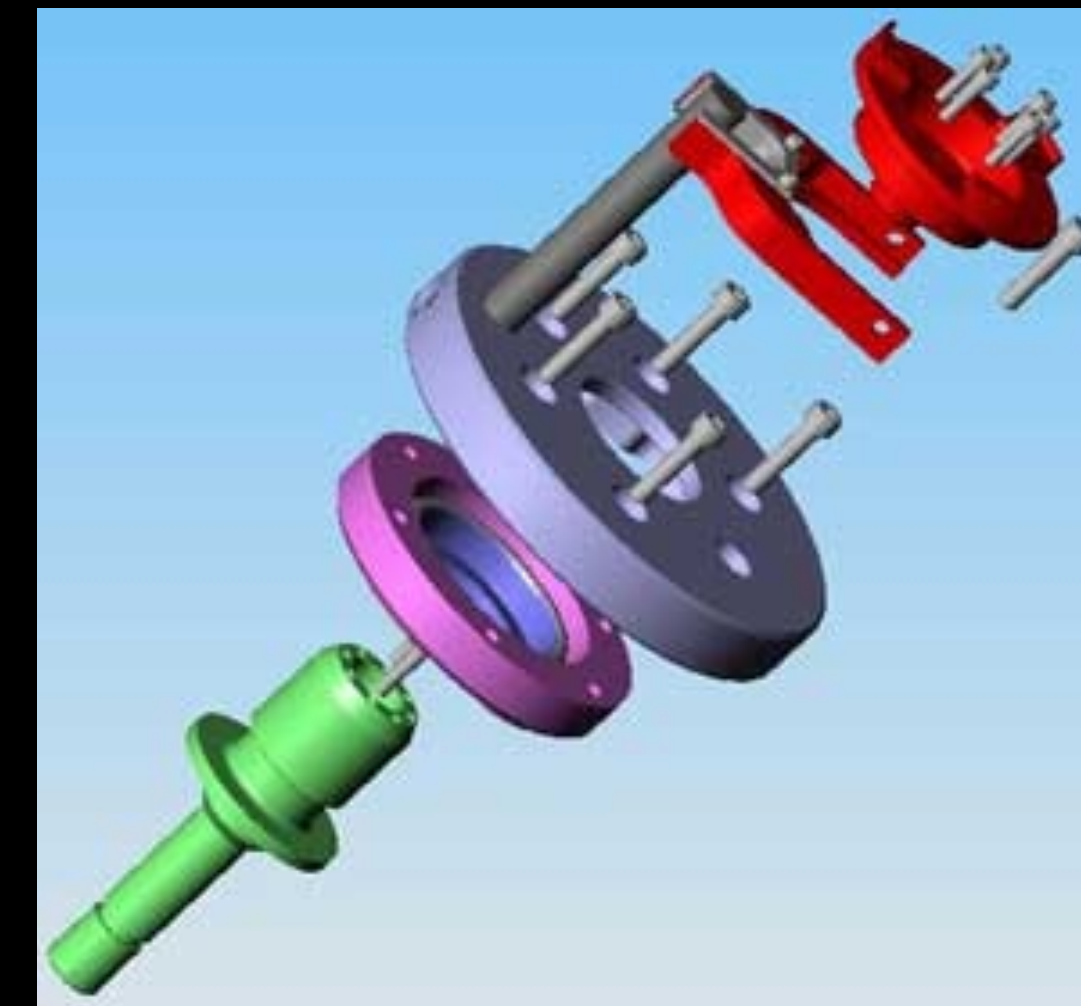
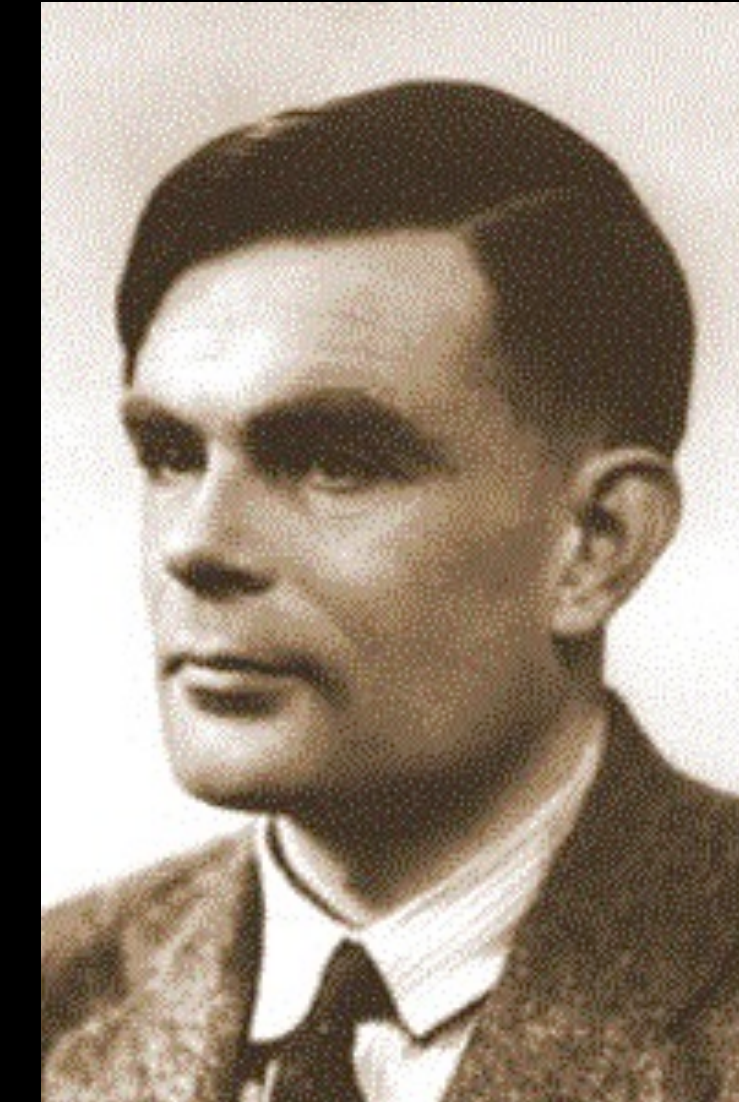
automation





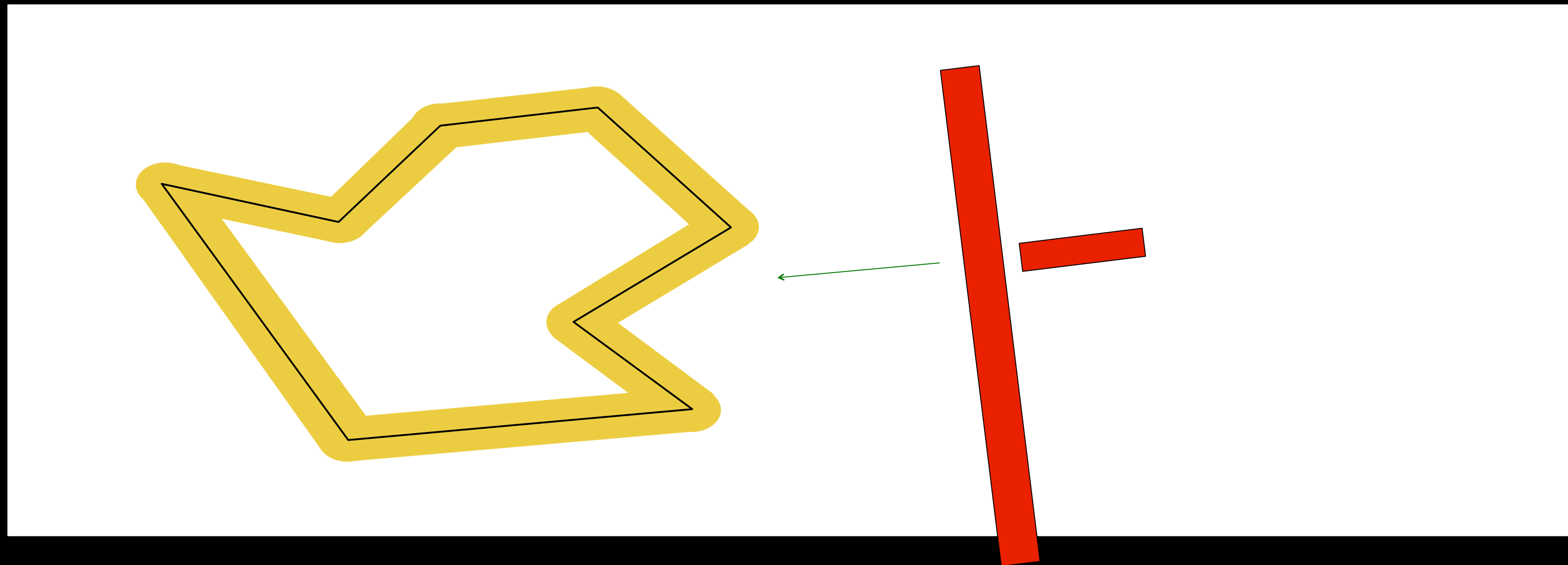
# Open Problems in Algorithmic Automation

- tangling
- tolerancing
- assembly line layout



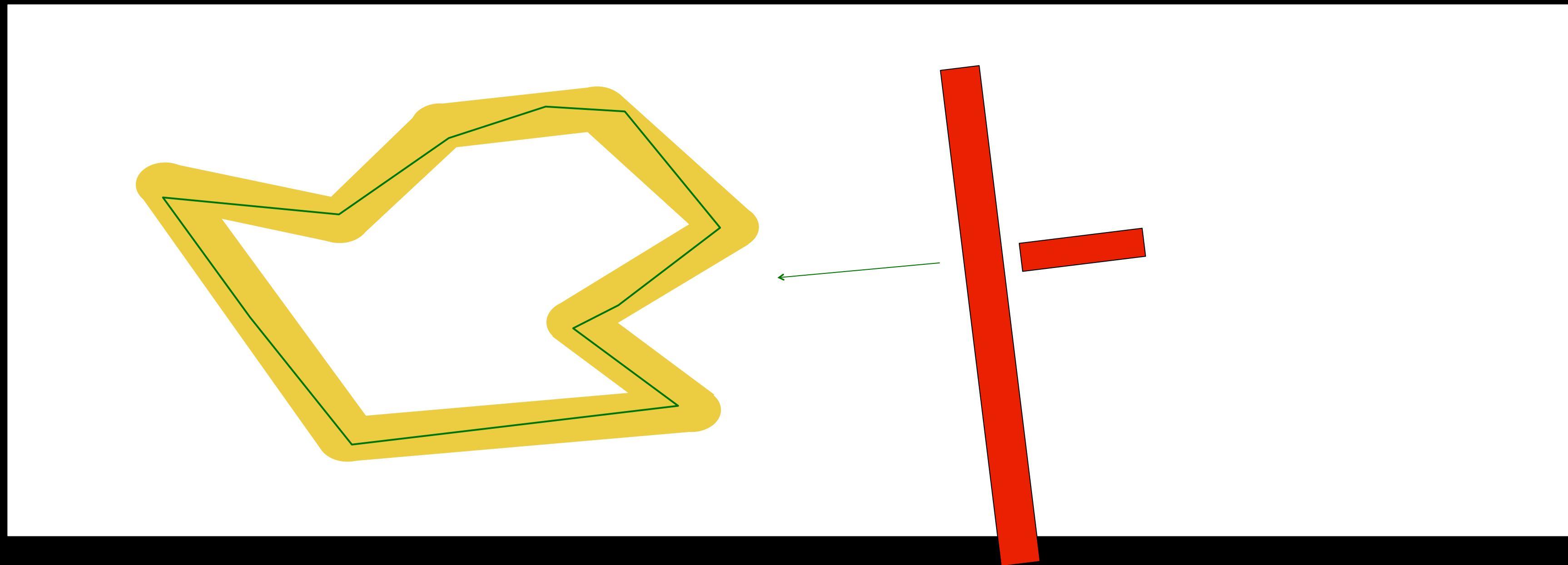
# Shape Uncertainty / Tolerancing

- For a given **task** and a **family of shapes**, plan actions that accomplish the task for any shape in the family



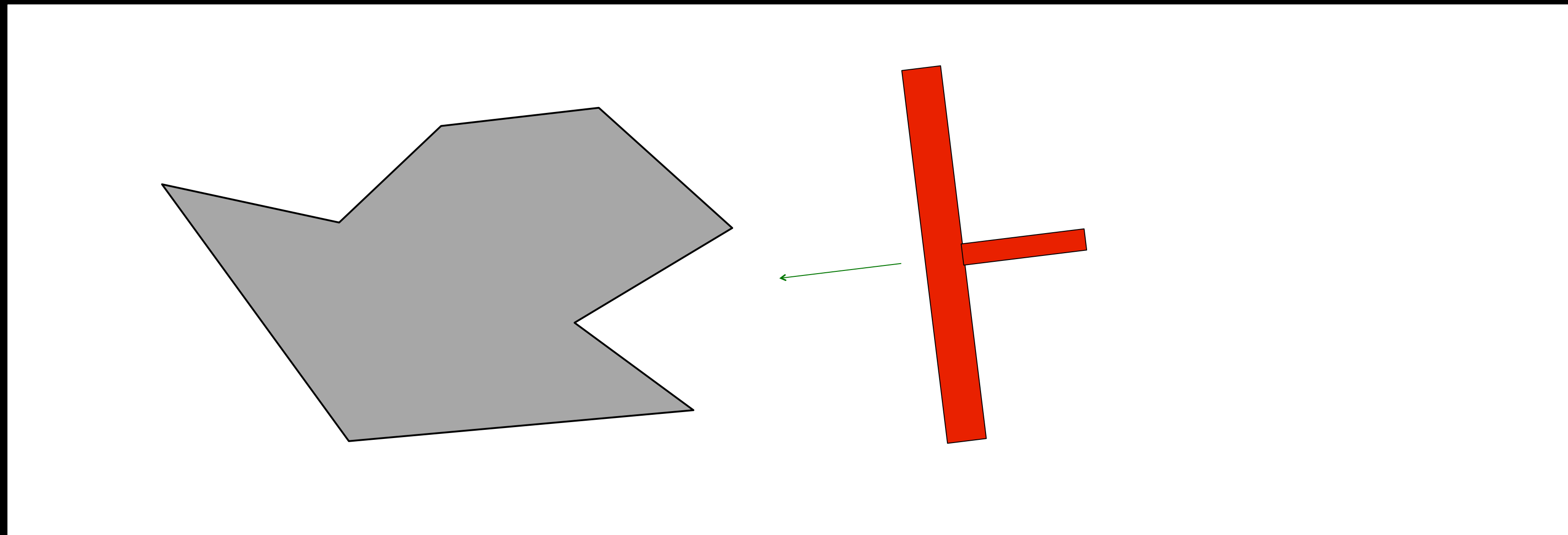
# Shape Uncertainty / Tolerancing

- For a given **task** and a **family of shapes**, plan actions that accomplish the task for any shape in the family



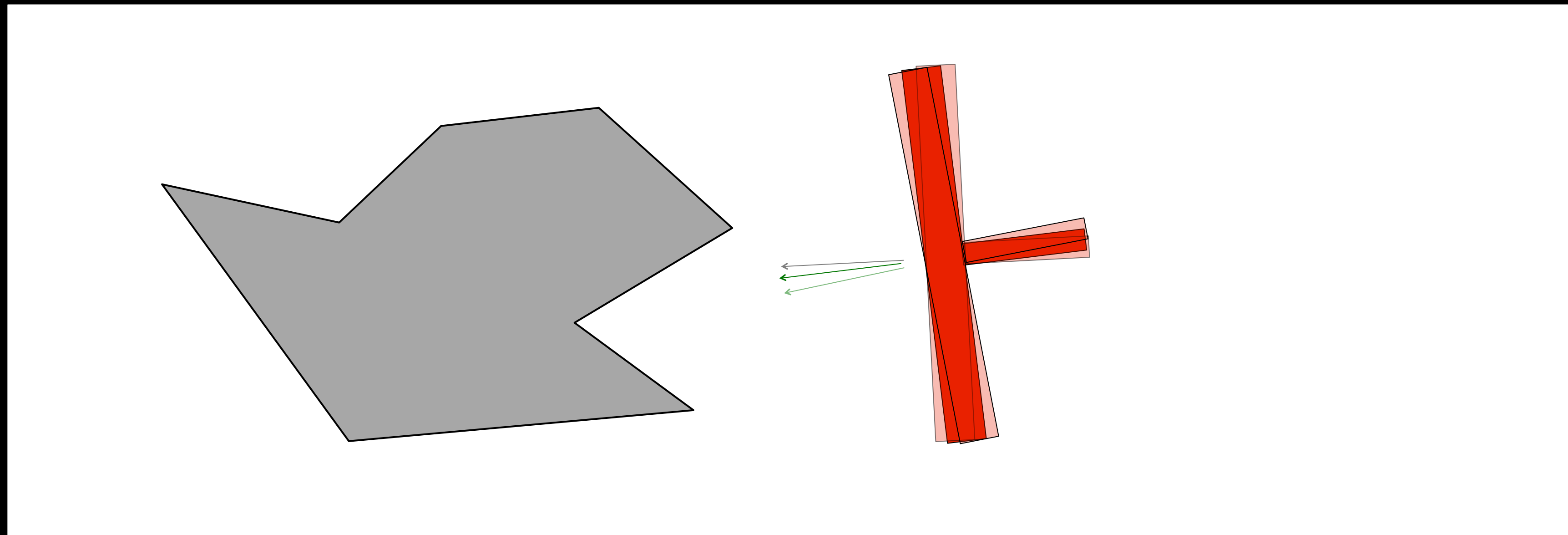
# Actuator Uncertainty

- For a given **part**, **task**, and a range of **perturbations** of any possible action, **plan actions** such that even the perturbed versions of the actions in the plan accomplish the task



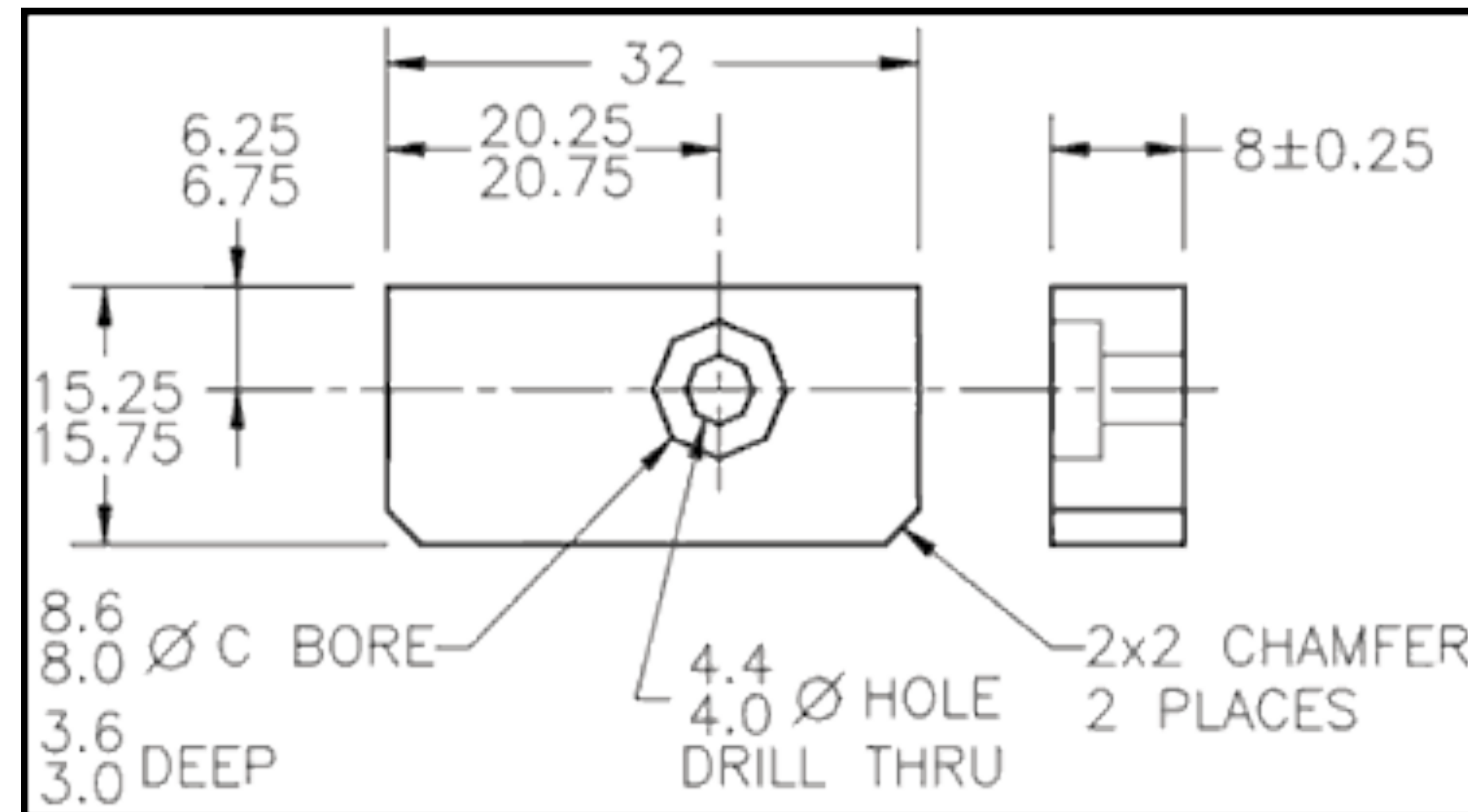
# Actuator Uncertainty

- For a given **part**, **task**, and a range of **perturbations** of any possible action, **plan actions** such that even the perturbed versions of the actions in the plan accomplish the task



# AMPLIFI (van der Stappen 13)

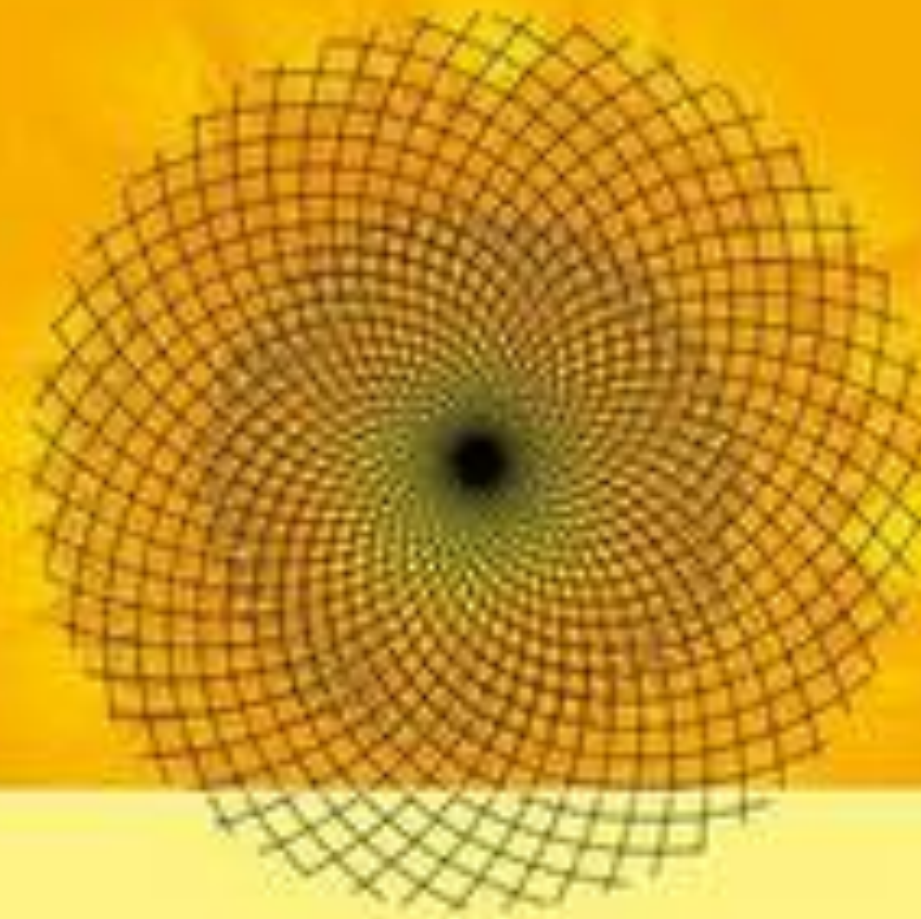
Algorithms for **m**anipulation **p**lanning with **i**mperfect parts and **i**naccurate manipulators



Example of Coordinate Tolerancing


Geometry and Computing 7

Efi Fogel  
Dan Halperin  
Ron Wein



# CGAL Arrangements and Their Applications

A Step-by-Step Guide

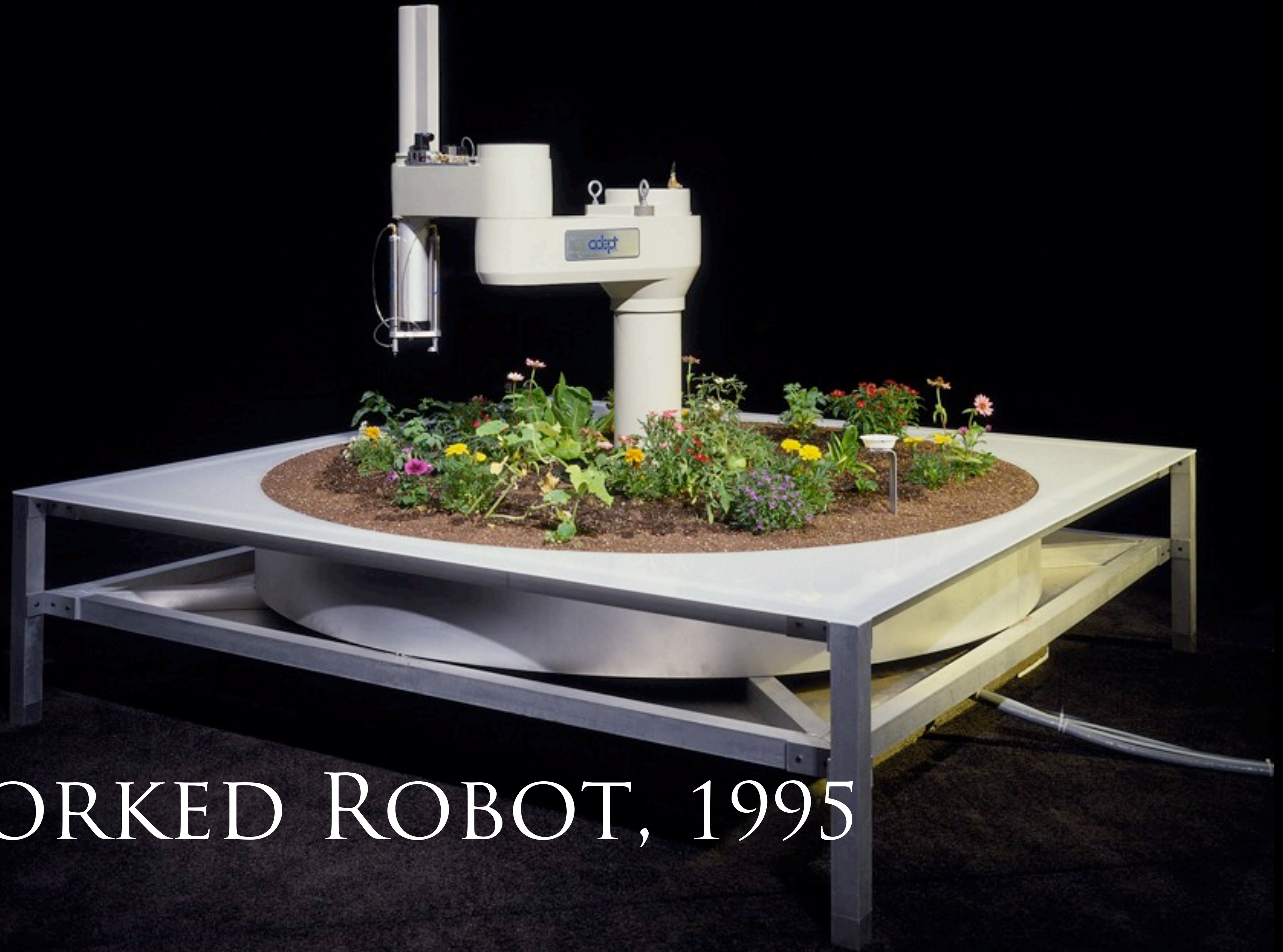
 Springer

# ASSEMBLY LINE (1910)



# ASSEMBLY LINE (2010)





# NETWORKED ROBOT, 1995

# GOOGLE'S ROBOTIC CAR



