Potential Field

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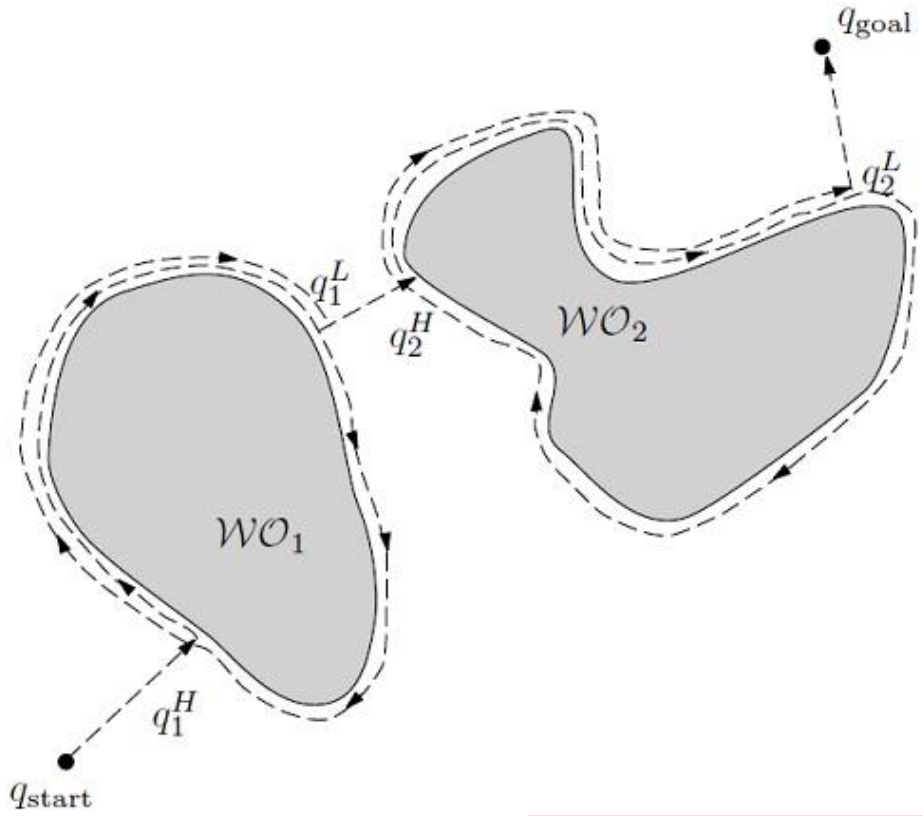
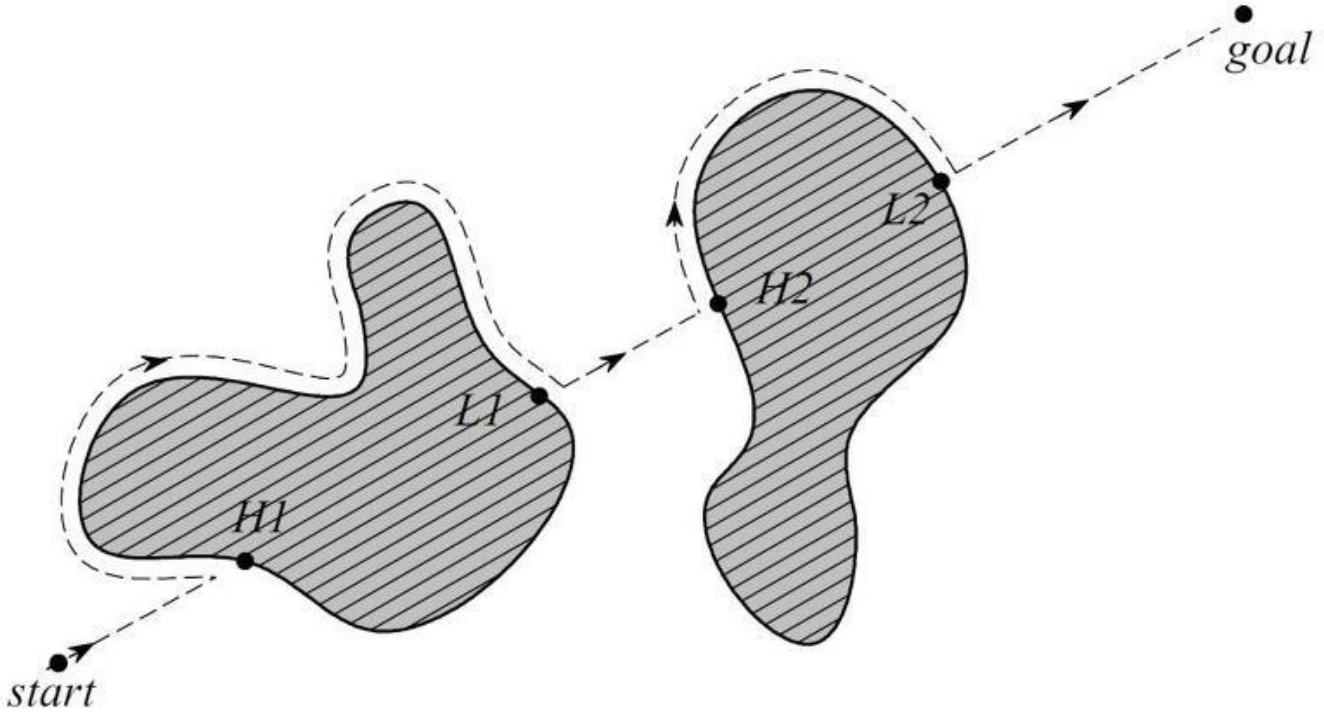
Quiz (10 pts)

- (2 pts) Is Bug 2 algorithm more efficient than Bug 1?
- (2 pts) What metric can be used to measure their efficiency?
- (3 pts) How to reduce the complexity of a visibility map
- (3 pts) Draw a graph to show how to use quad-tree for cell decomposition

Bug 1 VS Bug 2

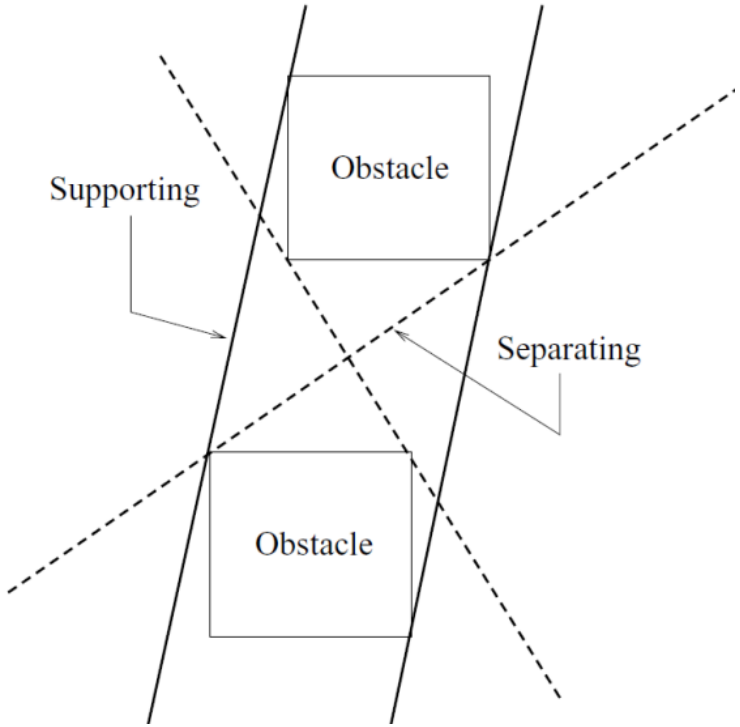


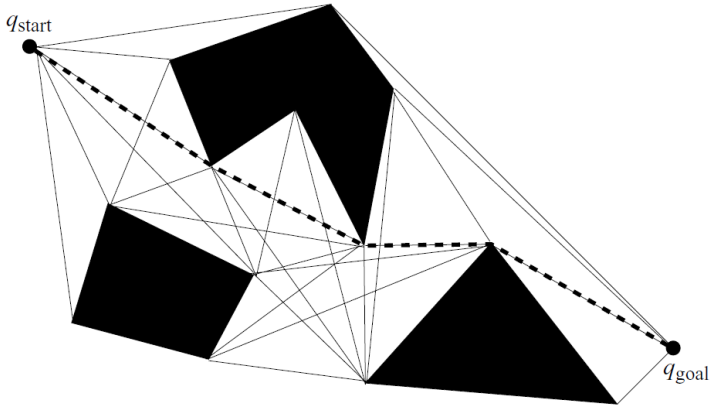


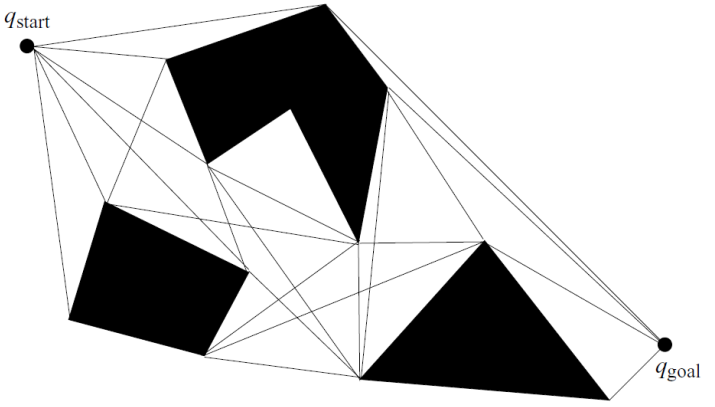
Ratio = Euclidian distance/Actual distance

Reduced Visibility Graph

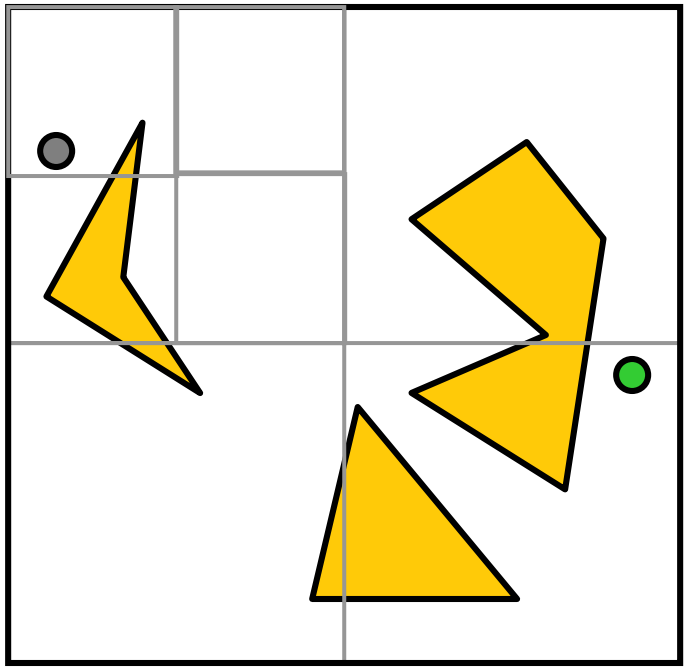
- Construct visibility graph from
  - Supporting and separating lines

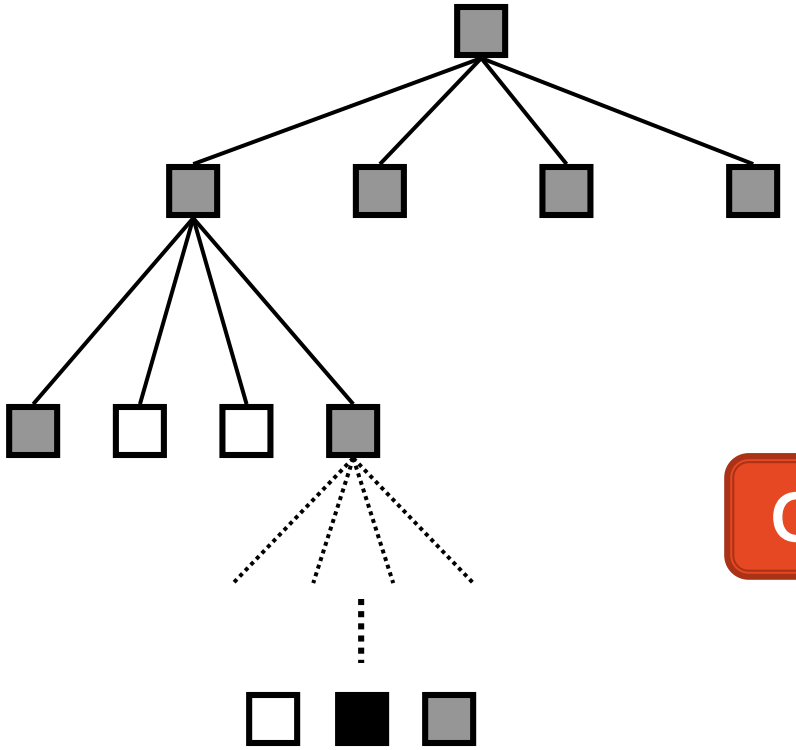






Cell decomposition – Approximate method





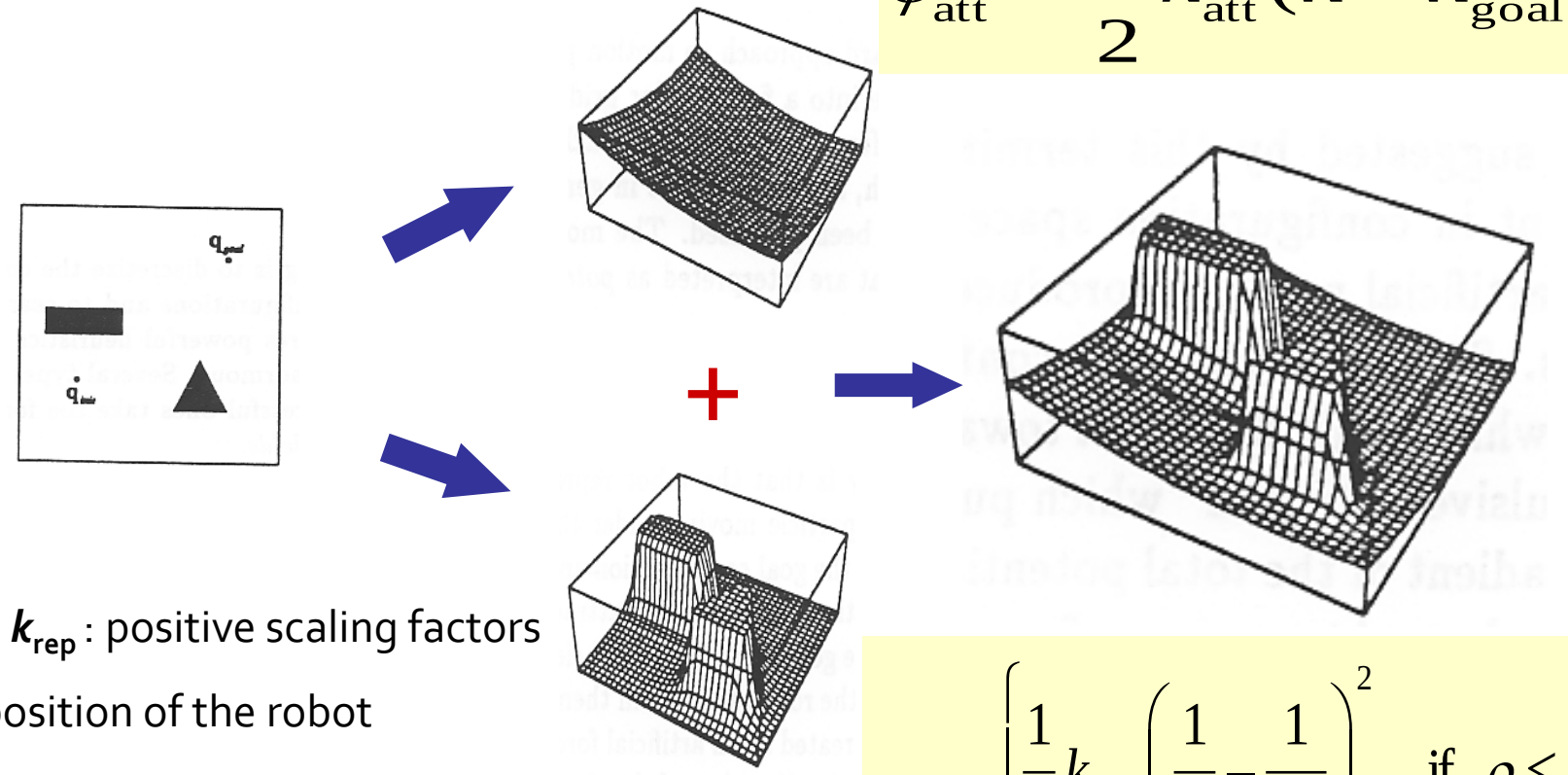
Quad-tree

empty mixed full

Potential Field

Potential field

$$\phi_{att} = \frac{1}{2} k_{att} (x - x_{goal})^2$$



k_{att}, k_{rep} : positive scaling factors

x : position of the robot

r : distance to the obstacle

r_o : distance of influence

$$\phi_{rep} = \begin{cases} \frac{1}{2} k_{rep} \left(\frac{1}{\rho} - \frac{1}{\rho_0} \right)^2 & \text{if } \rho \le \rho_0, \\ 0 & \text{if } \rho > \rho_0 \end{cases}$$

Attractive and repulsive forces

$$F_{\text{att}} = -\nabla \phi_{\text{att}} = -k_{\text{att}}(x - x_{\text{goal}})$$

$$F_{\text{rep}} = -\nabla \phi_{\text{rep}} = \begin{cases} k_{\text{rep}} \left(\frac{1}{\rho} - \frac{1}{\rho_0} \right) \frac{1}{\rho^2} \frac{\partial \rho}{\partial x} & \text{if } \rho \le \rho_0, \\ 0 & \text{if } \rho > \rho_0 \end{cases}$$

k_{att}, k_{rep} : positive scaling factors

x : position of the robot

r : distance to the obstacle

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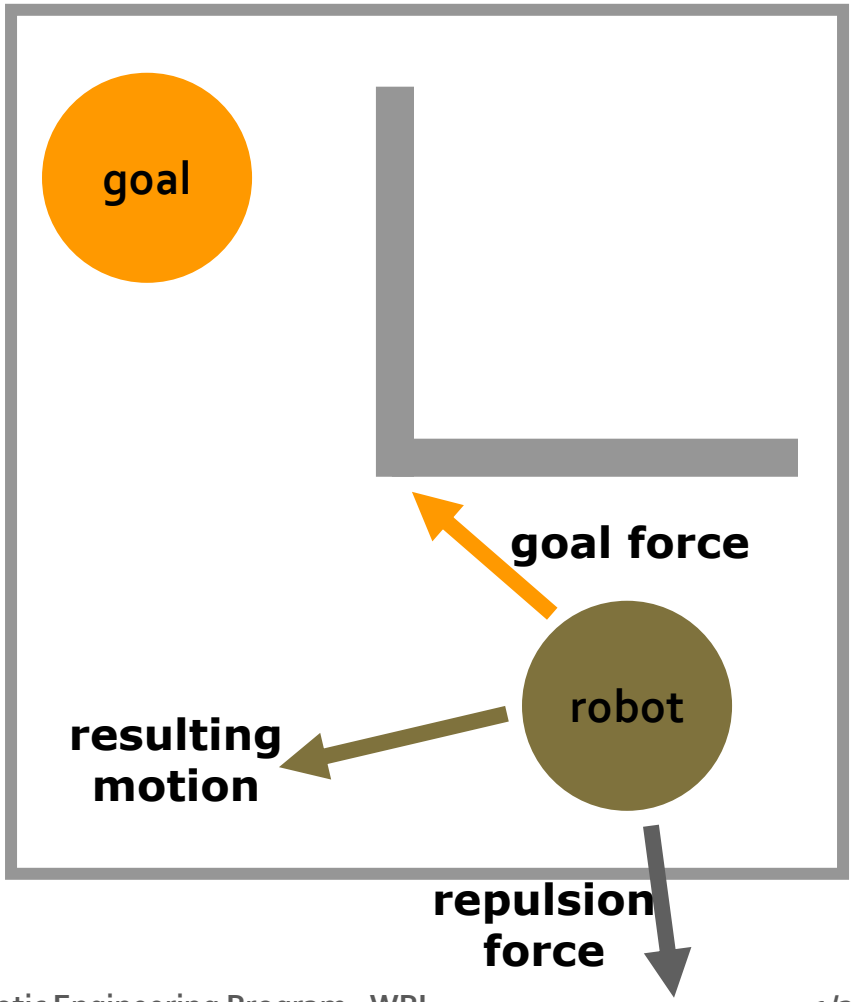
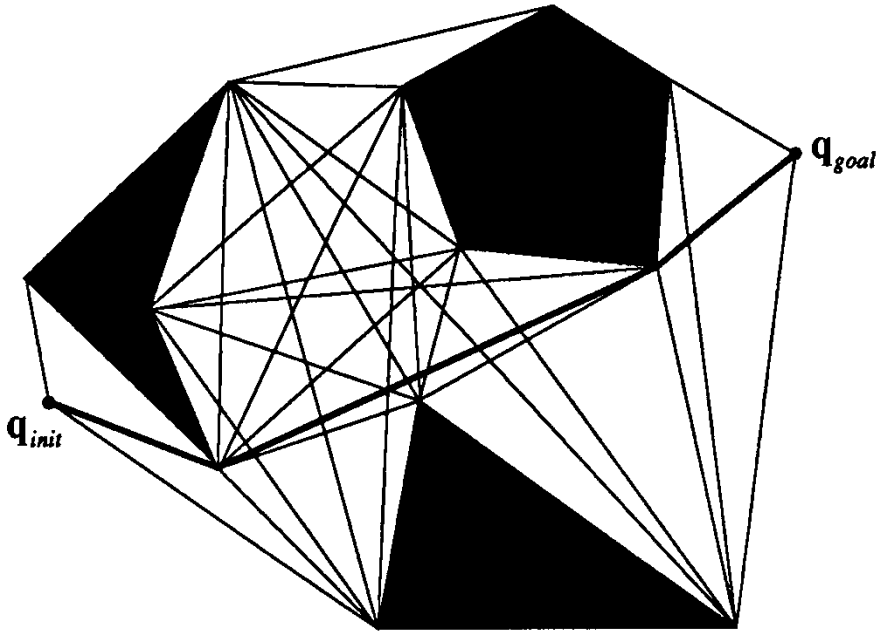
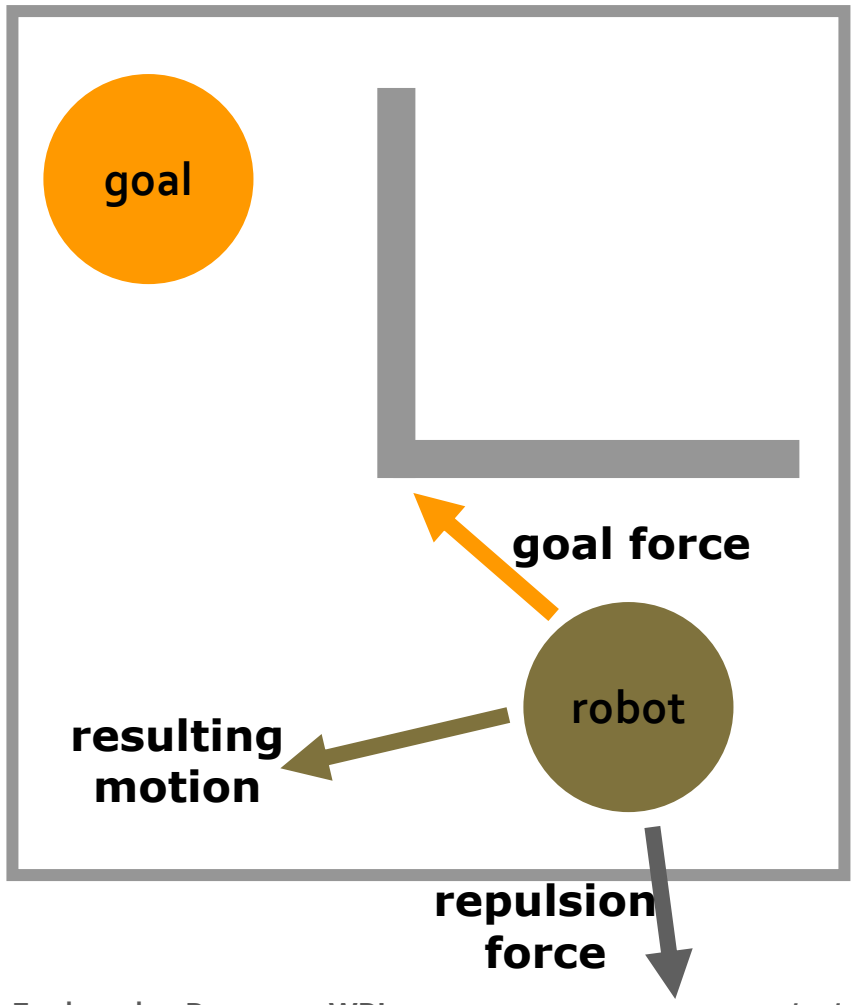
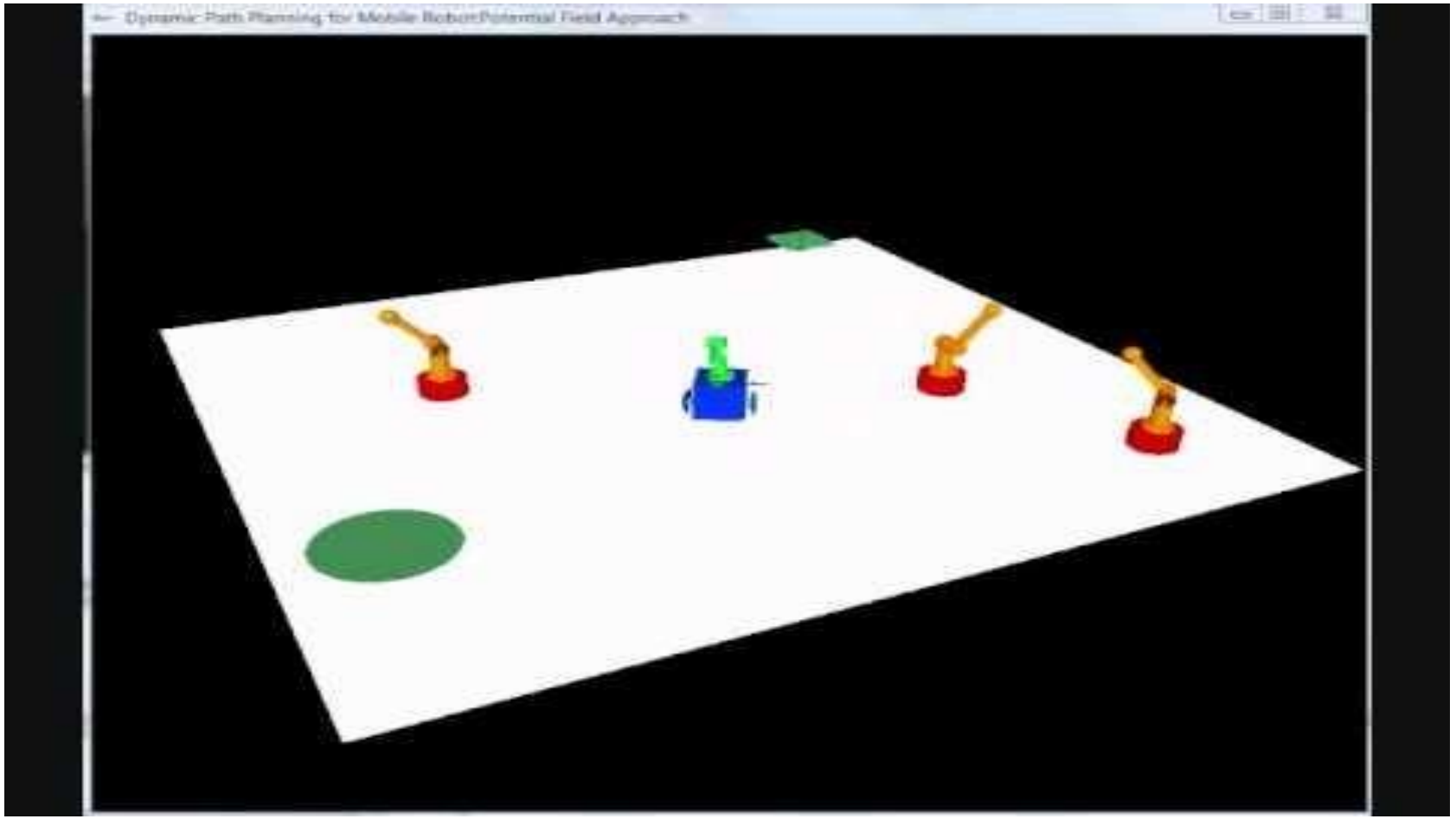


Potential field vs roadmap

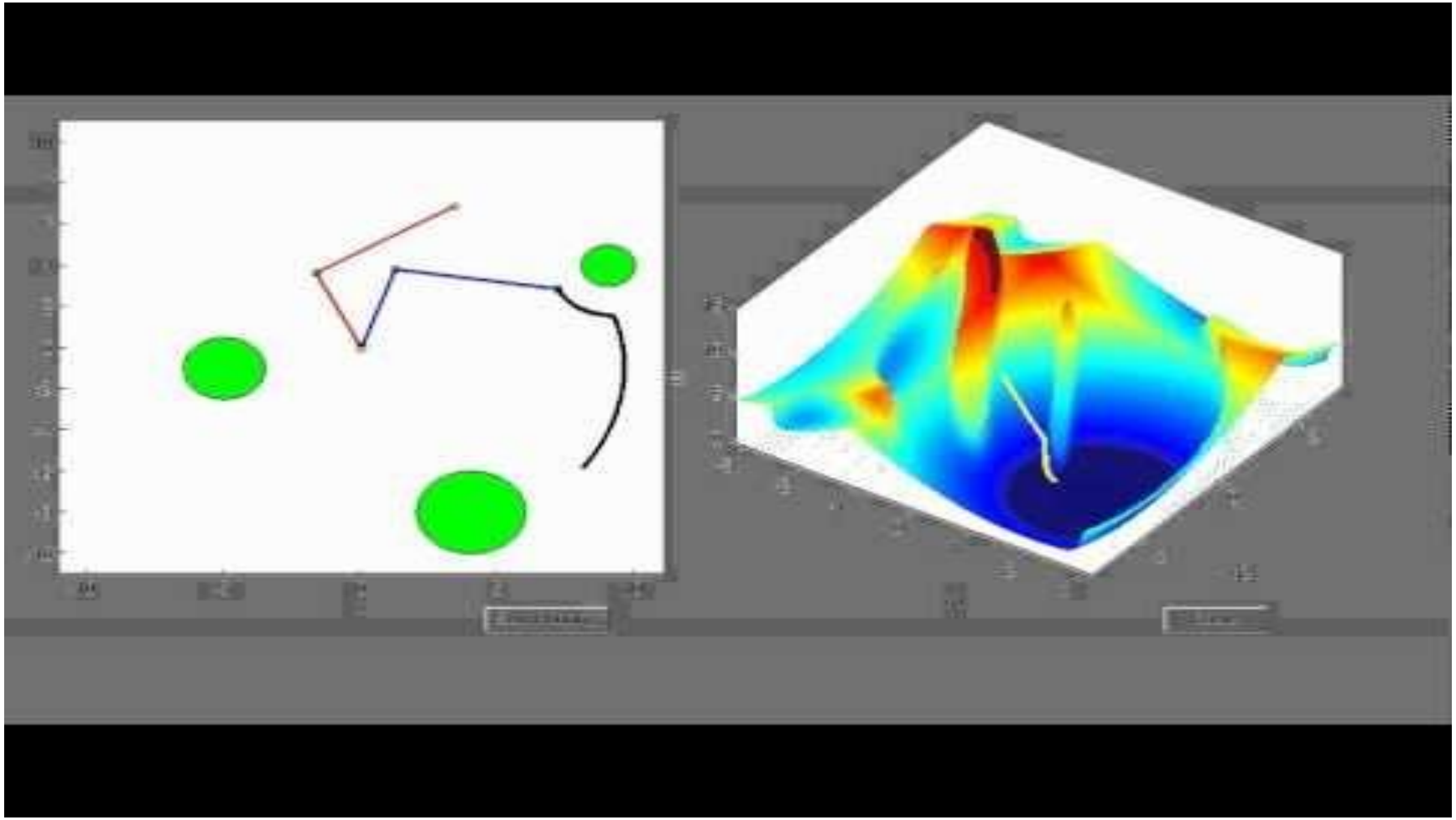




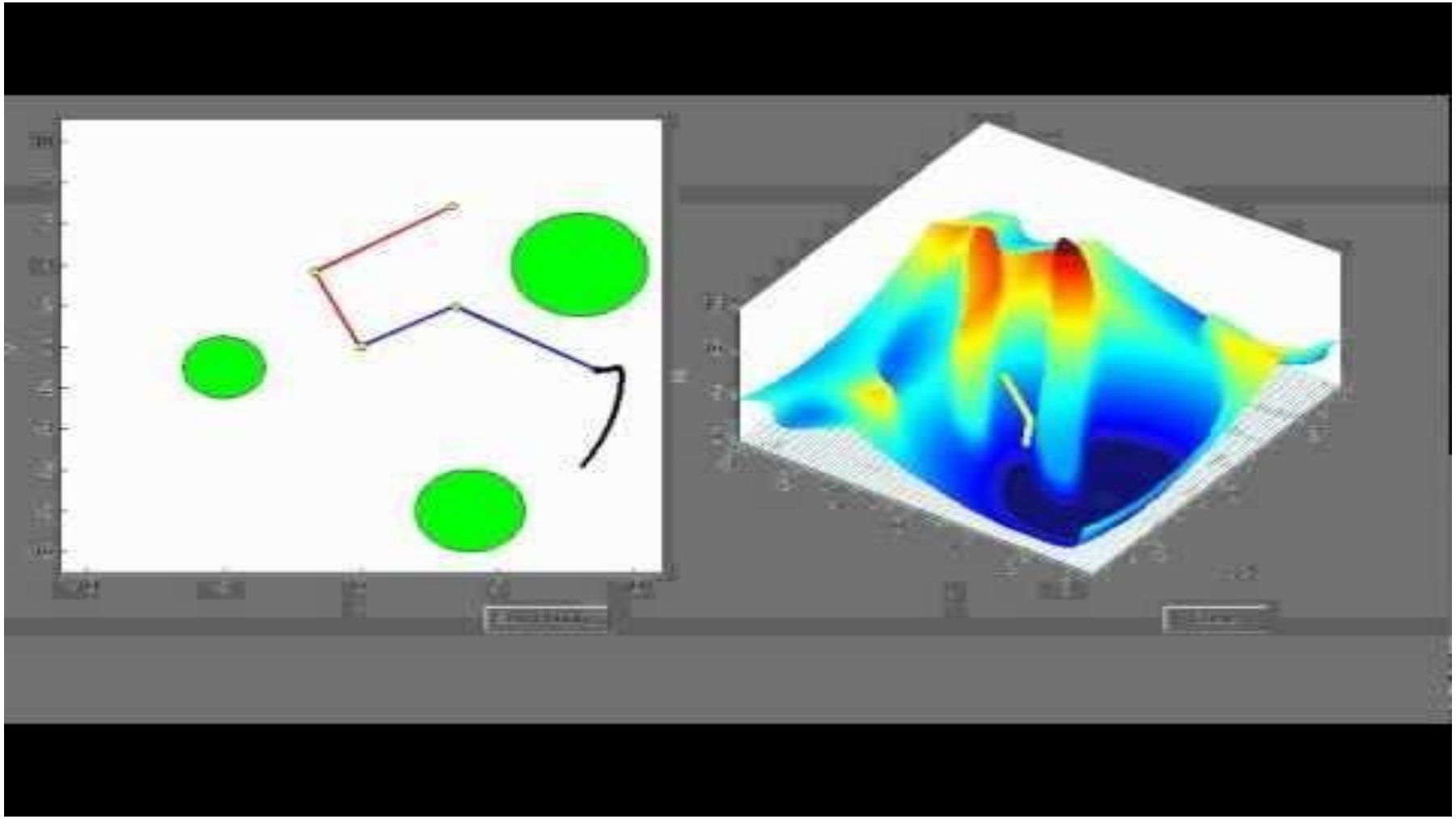
Navigation in dynamic environment



Successful case

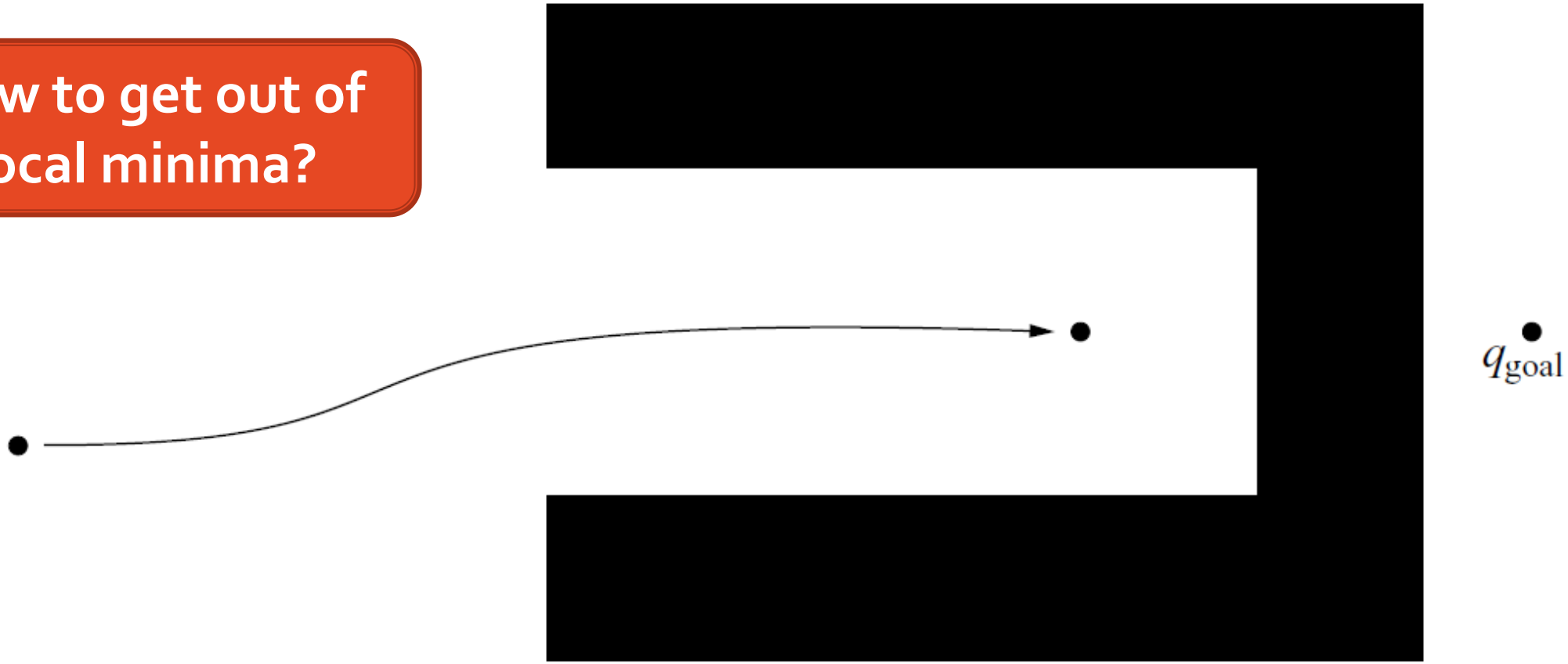


Failed case

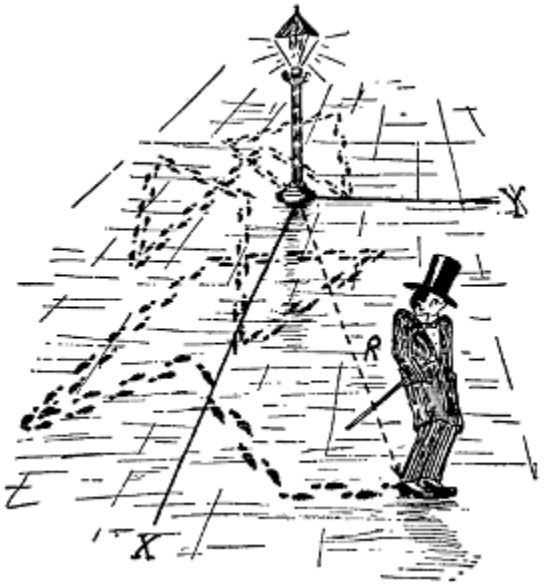


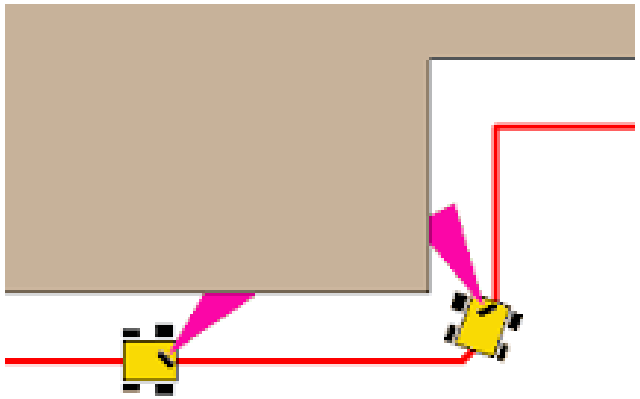
Local minima

How to get out of local minima?



How to get out of local minima





Construct a better potential field function

- Global minimum at the goal
- No local minima
- Grows to infinity near obstacles
- Smooth

Hand-engineered

Completeness

- A **complete** motion planner
  - Always returns a solution when one exists
  - Indicates that no such solution exists otherwise

Are these motion planners complete?

- Visibility graph?
- Exact cell decomposition?
- Approximate cell decomposition?
- Potential field?

Project Assignment

Coordinated motion of mobile manipulator nursing robot

- Sihui Li (leader) <sli16@wpi.edu>
- Yan Wang <ywang28@wpi.edu>
- James Kuszmaul <jbkuszmaul@wpi.edu>
- Vishnu rudrasamudram <vrudrasamudram@wpi.edu>
- Yun Qin <yqin@wpi.edu>
- Guled Elmi

- Arch-manager
  - Sihui Li <sli16@wpi.edu>

Dexterous arm-hand and bimanual coordination

- Yudong Yu <yyu6@wpi.edu>
- Joseph Schornak <jgschornak@wpi.edu>
- Abhilasha Rathod <arathod@wpi.edu>
- Shou-Shan Chiang <schiang@wpi.edu>
- Shakthi Sharavanan Duraimurugan <sduraimurugan@wpi.edu>

- Arch-manager
  - Sihui Li <sli16@wpi.edu>

Physical human-robot interaction based human intent prediction and object affordance

- Heramb Nemlekar (leader) <hsnemlekar@wpi.edu>
- John Chiodini <jpchiodini@wpi.edu>
- Abhijeet Thakan <amthakan@wpi.edu>
- Ari Elfenbein <aselfenbein@wpi.edu>
- Shakthi Sharavanan Duraimurugan <sduraimurugan@wpi.edu>
- Vishnu Radhakrishnan <vradhakrishnan@wpi.edu>

- Arch-manager
  - Gunnar Horve <gchorve@wpi.edu>

High-level motion planning in physical human-robot interaction

- Max Merlin (leader) <mtmerlin@wpi.edu>
- Nishant Doshi <ndoshi@wpi.edu>
- Binxin Liu <bliu@wpi.edu>
- Prakash Baskaran <pbaskaran@wpi.edu>
- Nalin Raut <nraut@wpi.edu>

- Arch-manager
  - Gunnar Horve <gchorve@wpi.edu>

Dexterous manipulation of multi-fingered robot hands (Small)

- Duong Nguyen <dnguyen2@wpi.edu>
- Gaurav Vikhe <gsvikhe@wpi.edu>

Path planning for a continuum surgical robot (Small)

- Arpit Gupta <agupta5@wpi.edu>
- Samruddhi Kadam <spkadam@wpi.edu>

Coordinated swarm robot navigation (small)

- Bhuvanna Chaitanya Reddy Perugu <bperugu@wpi.edu>
- Ashwin Sahasrabudhe <amsahasrabudhe@wpi.edu>
- Chris Dalessio <cdalessio@wpi.edu>

Online motion planning in dynamic virtual environment (Small)

- Nathaniel Goldfarb <nagoldfarb@wpi.edu>

Team management

General Guidelines

- Prof Mike Gennert's Project Guidelines
  - http://web.cs.wpi.edu/~michaelg/projects/guidelines.html
- Generally applied to our course project

Project meeting schedule

- Schedule your first team meeting (week of Jan 29)
- Standard projects – Must have me and/or TA involved
  - Each team book a **one-hour** slot on when2meet: https://www.when2meet.com/?6605449-tWLuJ
  - Agree on a time that every team member can show up
  - Must have overlap with me or TA
  - Cannot overlap with other team
- Small projects
  - Schedule your kick-off meeting with Prof Pinciroli or Fichera

Responsibility of Team leader

- Project contacts will take the lead before a leader is elected.

- Leader's responsibility
  - Take the lead in research
  - Coordinate project sub-tasks
  - Keep tracking on task progress
  - Preside project meeting and group literature review meeting
  - Coordinate report writing and presentation
  - Report directly to Prof Li

Responsibility of team members

- Deliver your commitment
- Be prepared and contribute to research discussion
- Make **essential** contribution to project
- Keep other team members updated of your progress
- Support team leader and help each other

Agenda for your first project meeting

- Team leader
- Weekly meeting Schedule
  - One for project progress
  - One for paper-reading discussion
- Communication channel
  - Setup your slack group
- High-level project task division
- Group literature review topics – important
  - May propose 2 topics for my review

Report

- Two reports
  - Project report
  - Literature review report
- Requirement
  - Update weekly, everyone should contribute
  - Prefer use overleaf latex project
  - Keep a list of papers, and reading notes
  - Follow the structure of engineering conference paper – prefer to use the same template

Project documentation

- Use lab GitRepo
  - http://solar-10.wpi.edu/RBE550/iml-internal
  - Create your own project branch
  - Write clear code documentation
- TA will create a project folder for each group
  - Backup everything
  - Be careful with file size
    - Large video – upload to youtube and document the links
    - Large data set – use lab network drive, talk to TA for access

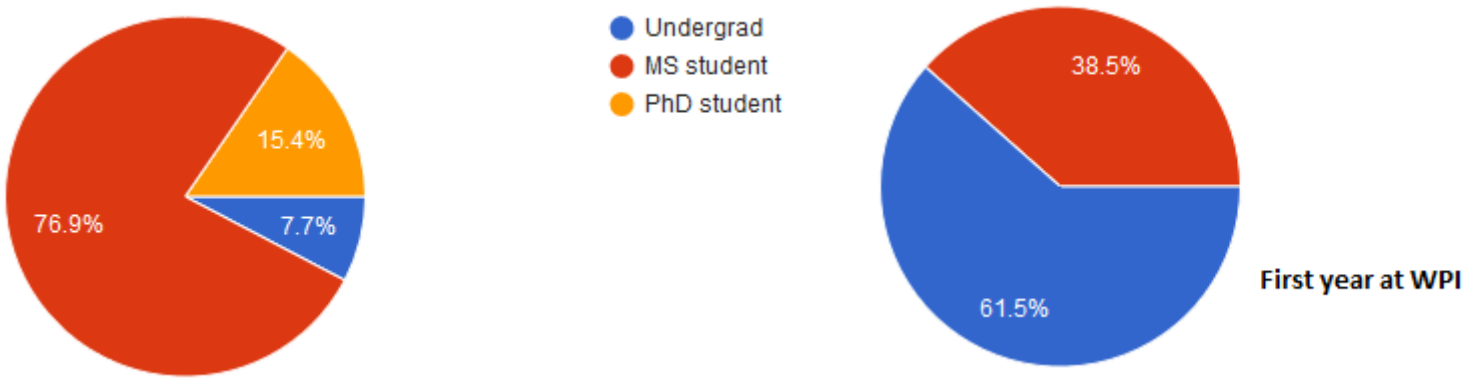
Project documentation

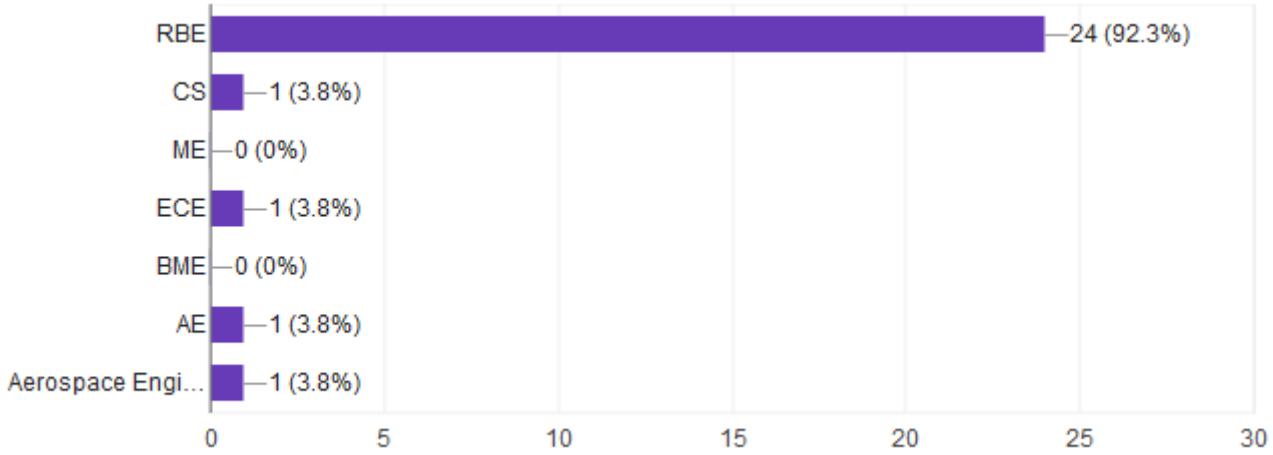
- Use wiki to create your project website
- Team leader
  - Manage project file system
  - Organize report on project and literature review
- Keep your own project log
  - Submit as an evidence of your project effort through the semester

Projects will be much harder than class lecture

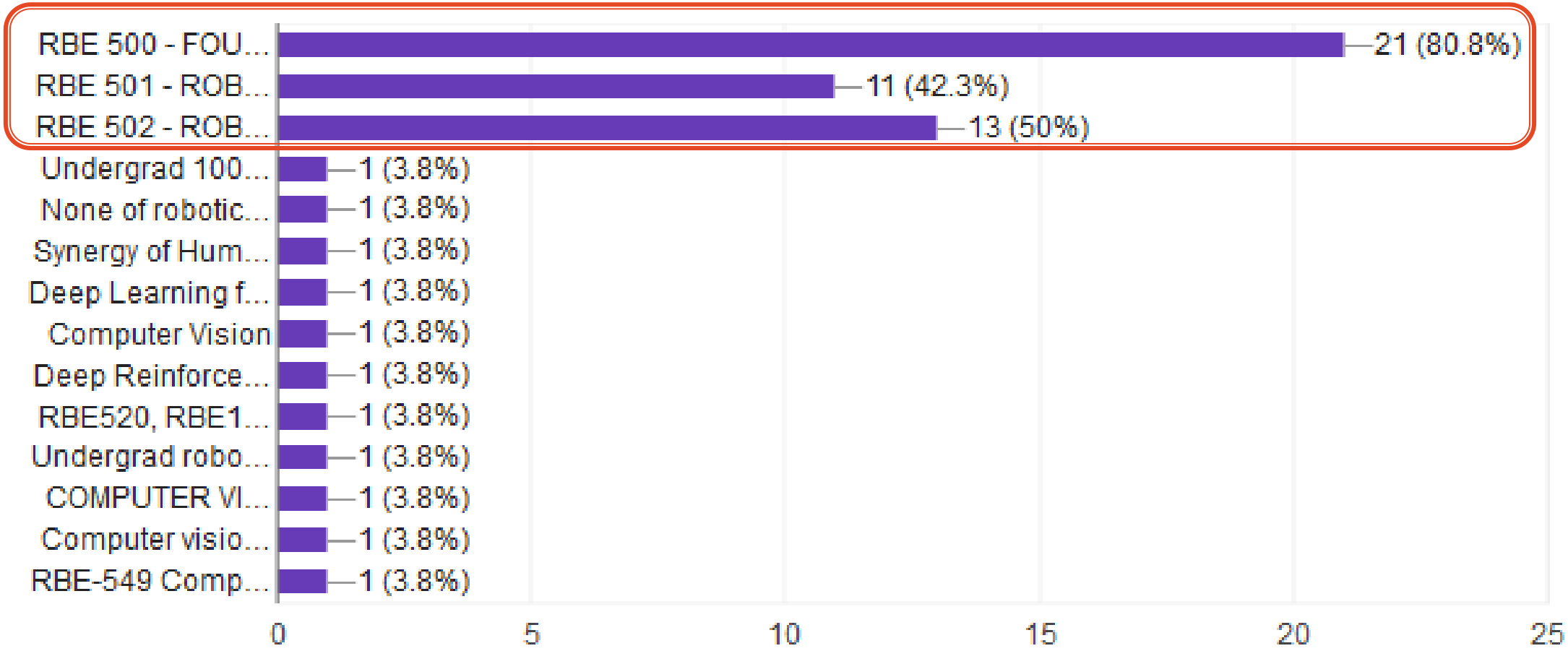
- Your intellectual challenge
  - Class lectures are the baseline your motion planning knowledge
  - Quizzes and assignments are too easy? Don't worry …
- Your research focus, depth, and passion
  - Class lectures introduces the fundamental concepts and methods
  - Class lectures address the needs of **ALL** students

Class Statistics (26/27 responses)

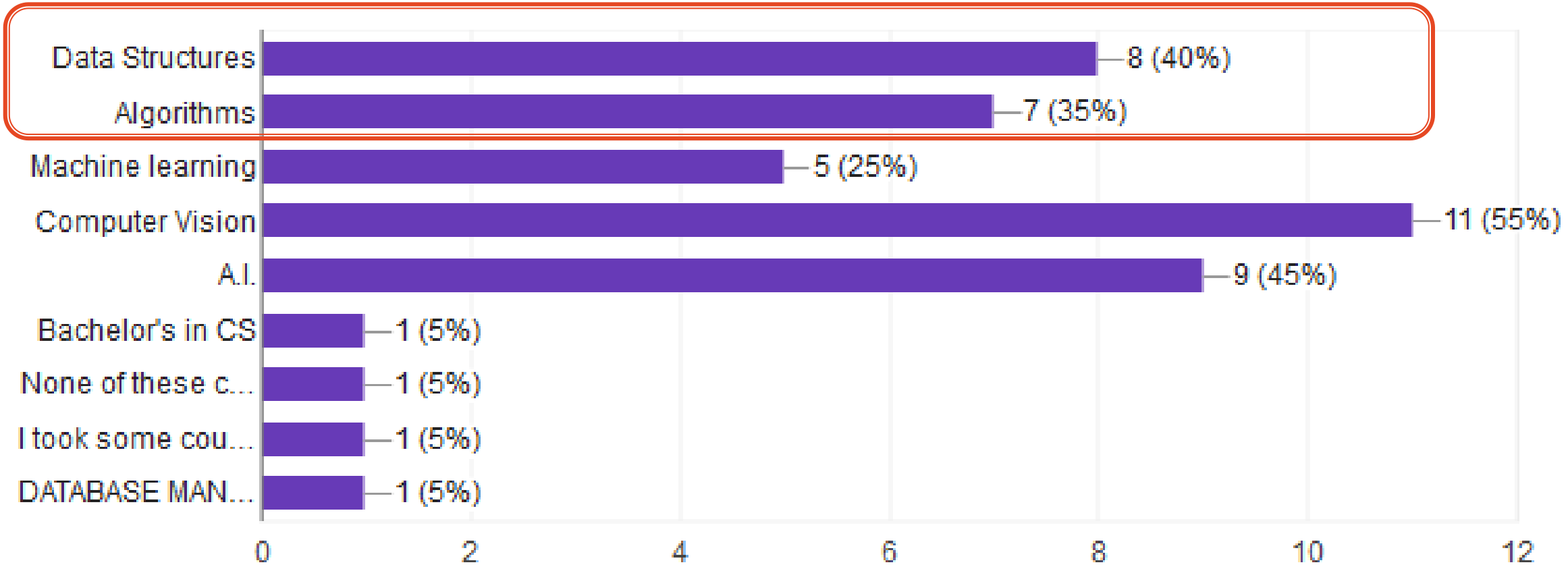




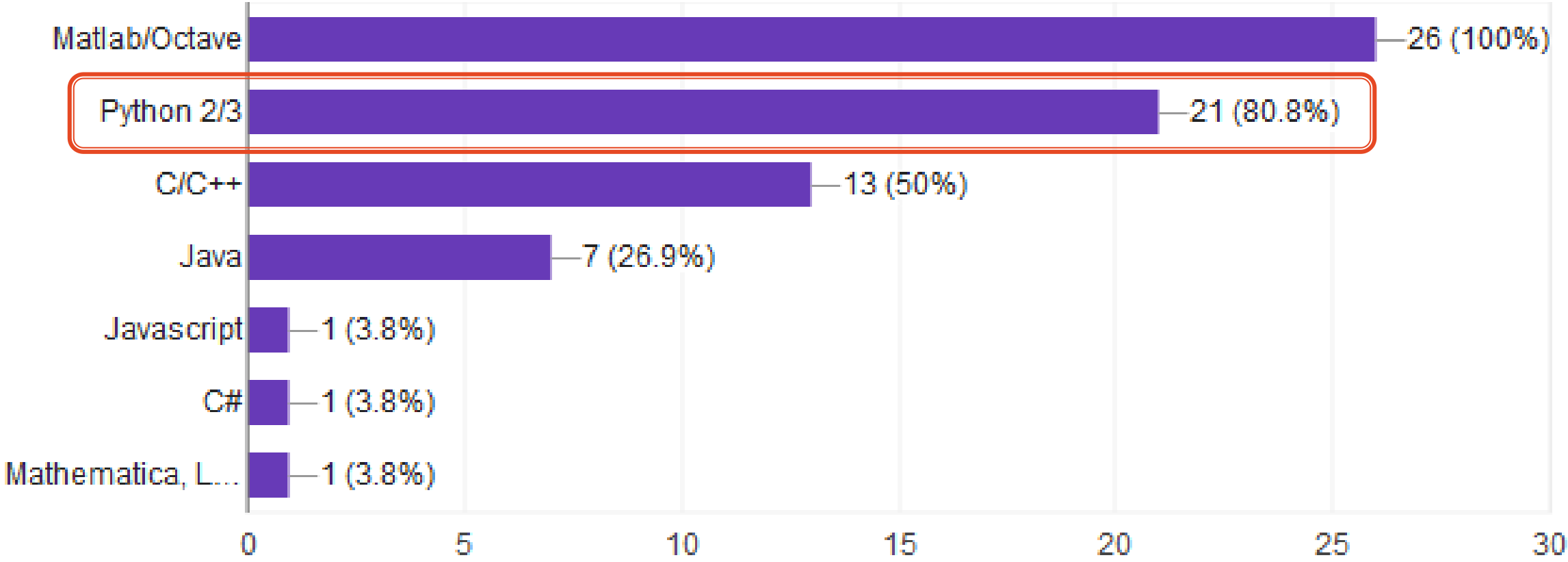
RBE courses – good



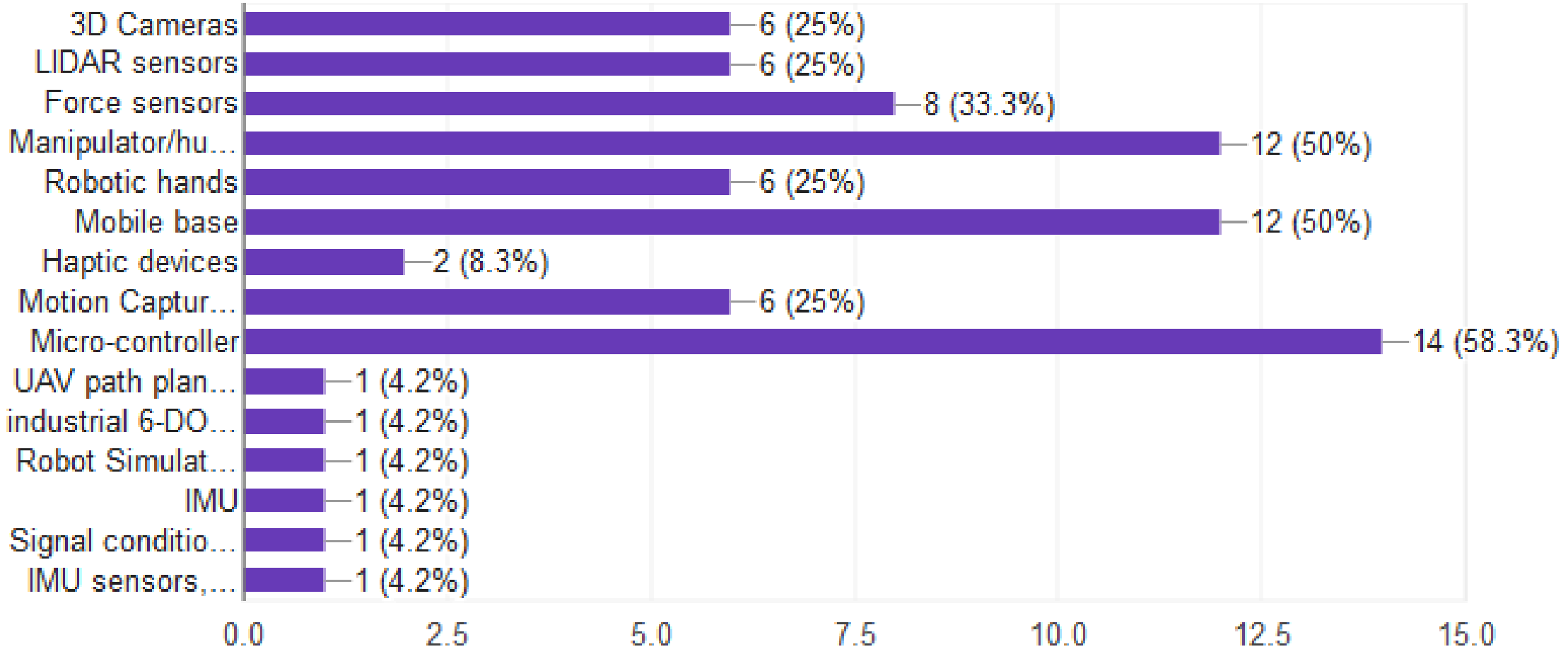
Knowledge in Algorithm



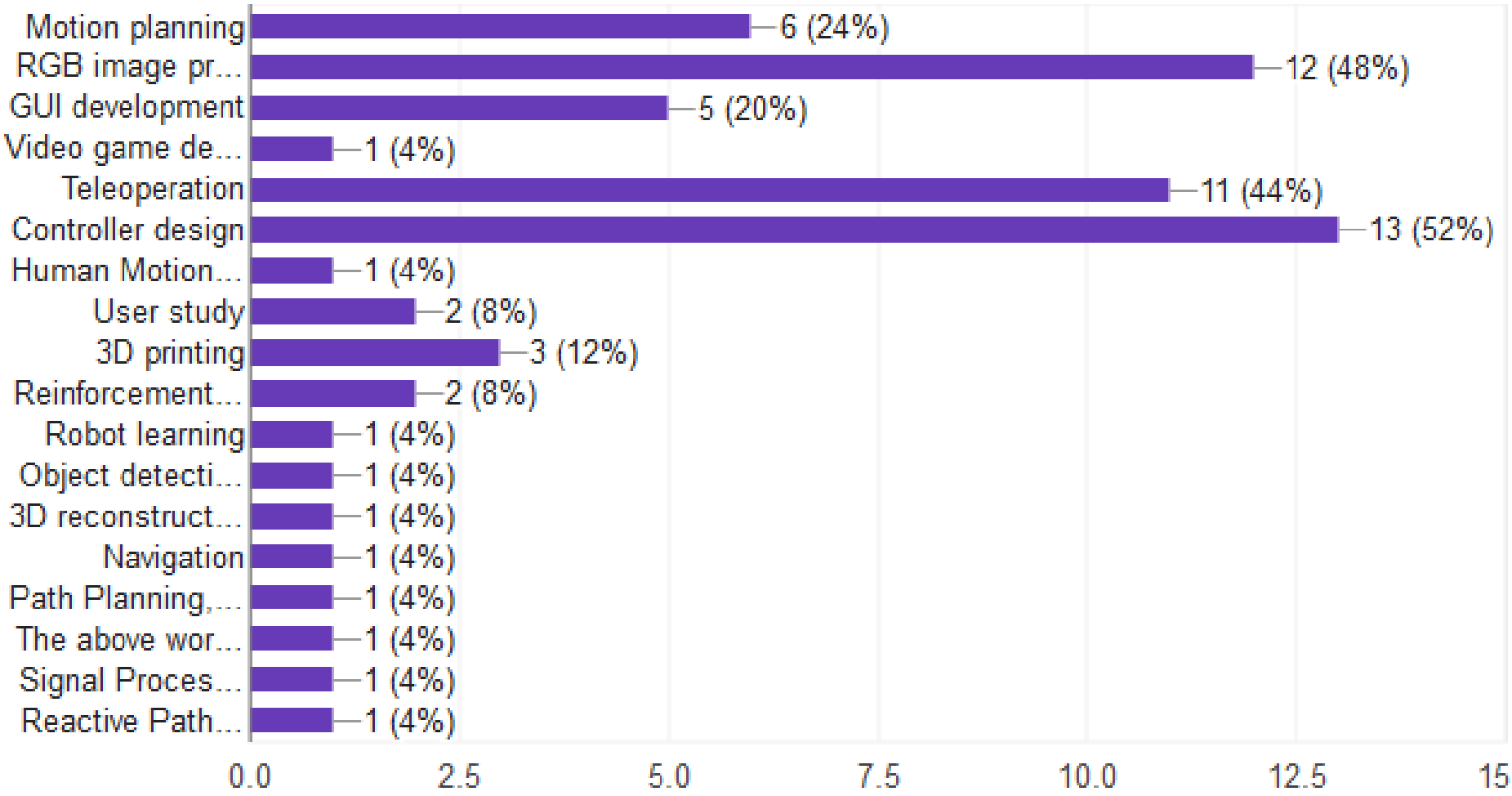
Coding Skills – Enough for course project



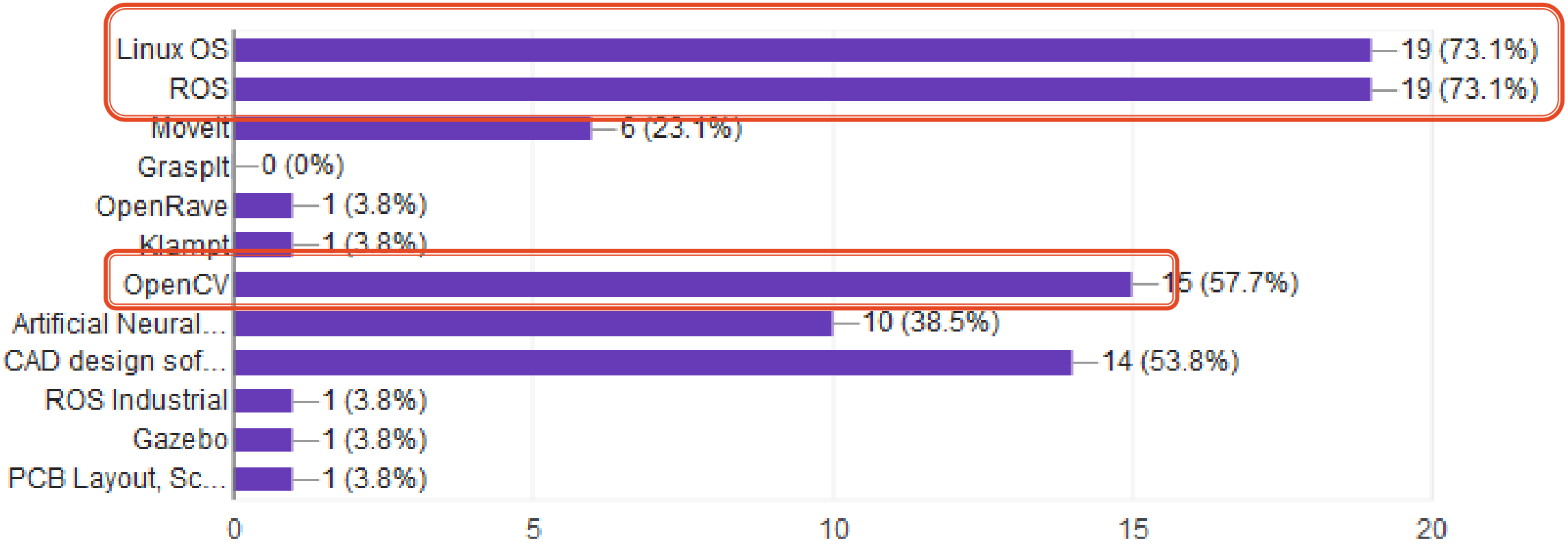
Hardware Experience – Good variety



Project experience



OS and software



Assignment – prepare for first project meeting

- Search on **Google scholar** for papers on your project topic
  - Key words provided in Lecture 2 – project introduction
  - Search for **recent** and **important** papers
  - Recent = less than 5 years
  - Important = ICRA, IROS, RSS conference + high-impact robotics journals (see http://www.hizook.com/blog/2011/11/02/impact-factors-robotics-journals)
  - Convenient if your project literature review is aligned with project, but not a requirement

Assignment – prepare for first project meeting

- Start to research on your project topic
  - List of title, link and abstract, sorted by year
- Summarize your thoughts on
  - The values of the papers you have briefly go through
  - Towards the project goal, what methods can be used
- Propose a sub-task for yourself
  - You may coordinate with another teammate to propose a shared sub-task
  - Need to be clear about your task division

Individual Assignment – Due on Wed (Jan 31)

- Your sub-task proposal
  - One page, submitted on Canvas
  - Propose your own sub-task under the project scope
  - Include problem formulation + methods + timeline
  - Your paper list: title + abstract + notes for your thoughts

- If you proposal a sub-task with another teammate
  - Submit one copy, with both of your name
  - Include a section for your task-sharing

Group Assignment – Due on Wed 31

- Selection of group literature review topic
  - One-page with
    - Topic title
    - Motivation and Significance – why you think this topic is important
    - Scope and focus – you may not be able to cover everything; be specific
  - Submit on Canvas, one copy per team
  - Helpful to keep a note for your first group meeting discussion

Next Friday (Jan 26) – TRINA workshop

- Coordinate with your teammates
- Objectives
  - Introduction to TRINA system (Hardware + software)
  - Help you setup workstation
- Requirement
  - Each group need to bring at least one workstation with
  - Ubuntu 16 and ROS kinetic installed
  - Prefer to be dual-boot. VM can be SUPER slow for what we need

Student talk – Heramb Nemlekar

End