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
Potential Field
Potential field

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

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

\( k_{\text{attr}} \) \( k_{\text{rep}} \): positive scaling factors

\( x \): position of the robot

\( r \): distance to the obstacle

\( r_0 \): distance of influence
Attractive and repulsive forces

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

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

\( k_{\text{att}}, k_{\text{rep}} \): positive scaling factors

\( x \): position of the robot

\( r \): distance to the obstacle

\( r_o \): distance of influence
Potential field vs roadmap

- Goal force
- Resulting motion
- Repulsion force

Diagram showing a robot moving towards a goal with repulsion forces acting on it.
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
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 <jbkuszm@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
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)

- First year at WPI:
  - Yes: 51.5%
  - No: 38.5%

- Program Affiliation:
  - RBE: 24 (92.3%)
  - CS: 1 (3.8%)
  - ME: 0 (0%)
  - ECE: 1 (3.8%)
  - BME: 0 (0%)
  - AE: 1 (3.8%)
  - Aerospace Eng.: 1 (3.8%)
RBE courses – good
Knowledge in Algorithm

- Data Structures: 8 (40%)
- Algorithms: 7 (35%)
- Machine Learning: 5 (25%)
- Computer Vision: 11 (55%)
- A.I.: 9 (45%)
- Bachelor's in CS: 1 (5%)
- None of these courses: 1 (5%)
- I took some course(s): 1 (5%)
- DATABASE MANAGEMENT: 1 (5%)
Coding Skills – Enough for course project

- Matlab/Octave: 26 (100%)
- Python 2/3: 21 (80.8%)
- C/C++: 13 (50%)
- Java: 7 (26.9%)
- Javascript: 1 (3.8%)
- C#: 1 (3.8%)
- Mathematica, L…: 1 (3.8%)
Hardware Experience – Good variety

- 3D Cameras: 6 (25%)
- LIDAR sensors: 6 (25%)
- Force sensors: 8 (33.3%)
- Manipulator/humanoid: 12 (50%)
- Robotic hands: 6 (25%)
- Mobile base: 12 (50%)
- Haptic devices: 2 (8.3%)
- Motion Capture: 6 (25%)
- Micro-controller: 14 (58.3%)
- UAV path planning: 1 (4.2%)
- Industrial 6-DOF arm: 1 (4.2%)
- Robot Simulation: 1 (4.2%)
- IMU: 1 (4.2%)
- Signal conditioning: 1 (4.2%)
- IMU sensors: 1 (4.2%)
Project experience

- Motion planning: 12 (48%)
- RGB image processing: 6 (24%)
- GUI development: 5 (20%)
- Video game development: 1 (4%)
- Teleoperation: 11 (44%)
- Controller design: 13 (52%)
- Human Motion: 1 (4%)
- User study: 2 (8%)
- 3D printing: 3 (12%)
- Reinforcement learning: 2 (8%)
- Robot learning: 1 (4%)
- Object detection: 1 (4%)
- 3D reconstruction: 1 (4%)
- Navigation: 1 (4%)
- Path Planning: 1 (4%)
- The above working: 1 (4%)
- Signal Processing: 1 (4%)
- Reactive Path Planning: 1 (4%)
OS and software

- Linux OS: 19 (73.1%)
- ROS: 19 (73.1%)
- Moveit: 6 (23.1%)
- Grasplet: 0 (0%)
- OpenRave: 1 (3.8%)
- Klampt: 1 (3.8%)
- OpenCV: 15 (57.7%)
- Artificial Neural...: 10 (38.5%)
- CAD design sof...: 14 (53.8%)
- ROS Industrial: 1 (3.8%)
- Gazebo: 1 (3.8%)
- PCB Layout, Sc...: 1 (3.8%)
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](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
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
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