



EECS 367 Intro. to Autonomous Robotics

ROB 320 Robot Operating Systems

Winter 2022

autorob.org

Approaches to motion planning • Bug algorithms: Bug[0-2], Tangent Bug

- Graph Search (fixed graph)
 - Depth-first, Breadth-first, Dijkstra, A-star, Greedy best-first
- Sampling-based Search (build graph):
 - Probabilistic Road Maps, Rapidly-exploring Random Trees
- **Optimization and local search:** •
 - Gradient descent, Potential fields, Simulated annealing, Wavefront

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Navigation (again)















Gradient descent: Energy potential converges at goal

a little warmer

start: cold

colder





heating up

a little warmer



start: cold

How do we define a potential field?

Potential Field

- A potential field is a differentiable function U(q) that maps configurations to scalar "energy" value
- At any q, gradient $\mathcal{W}(q)$ is the vector that maximally increases U
- At goal q_{goal} , energy is minimized such that $\nabla U(q_{goal}) = 0$
- Navigation by descending field VU(q) to goal

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Gradient Descent Algorithm:

$$q_{path}[0] \leftarrow q_{start}$$

 $i \leftarrow 0$
while $(|| \mathcal{W}(q[i])|| > \varepsilon)$
 $q_{path}[i+1] \leftarrow q_{path}[i] - \alpha \mathcal{W}(q_{path}[i])$
 $i \leftarrow i+1$
end
Derivative assumed to be direct
of steepest ascent away from g
 $\mathbf{x}_{n+1} = \mathbf{x}_n - \gamma_n \nabla F(\mathbf{x}_n)$

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Potential Energy



- Energy stored in a physical system
- Kinetic motion caused by system moving to lower energy state
- For objects acting only w.r.t. gravity
 - potential_energy = mass*height*gravity

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Charged Particle Example

Positively charged particle follows potential energy to goal



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Convergent Potentials let's call these "attractor landscapes"

Start



Goal

basin of attraction



2D potential navigation

z: height indicates potential at location

1.2

0.8

0.6

0.4

0.2

0

100

basin of attraction

 $q_d = Goal$

50



x-y plane: robot position





top view

"Cone" Attractor

Start

w: weight $(q - q_d)$: direction $||q - q_d||$: distance

side view

Goal





top view

"Cone" Attractor

Start

w: weight $(q - q_d)$: direction $||q - q_d||$: distance

Goal

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side view





$\nabla U(q) = w(q - q_d)/||q - q_d||$ q = Start



top view

"Cone" Attractor

Start

w: weight $(q_d - q)$: direction $||q_d - q||$: distance

Goal

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side view





top view

x = Start

"Cone" Attractor

Start

w: weight (< 1) $(q - q_d)$: direction $||q - q_d||$: distance

Goal side view



Can we modulate the range of a potential field?

"Bowl" Attractor $\nabla U(q) = exp(-||q - q_d||/w) (q - q_d)$



top view



side view



C \leftarrow \rightarrow



Can we combine multiple potentials?



Multiple potentials

Output of potential field is a vector

Combine multiple potentials through vector summation

$U(q) = \sum_{i} U_{i}(q)$



describe performance for this case





describe performance for this case









add sum of repulsive potentials $U(q) = U_{attracts}(q) + U_{repellors}(q)$

40

Goal

70







reverse direction

 $\nabla U(q) = w(q_d-q)/||q_d-q||$



top view

"Cone" Repellor potential problems?



Start



side view



top view

"Bowl" Repellor





repellor should only have local influence, repelling only around boundary improves path



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2 Obstacle example





path from descent on gradient field

combined potential





resulting

gradient field

describe performance for this case with cone attractor to goal and bowl repellors with limited weight

70



describe performance for this case with cone attractor to goal and bowl repellors with limited weight


describe performance for this case with cone attractor to goal and bowl repellors with limited weight

70

Goal

380

4(



260

Current

describe performance for this case with cone attractor to goal and bowl repellors with limited weight

70

Goal

26

380

4(



260

Current



Local Minima

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describe performance for this case



describe performance for this case



describe performance for this case











pfield.m [1 5 8 12]

matlab example

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pfield.m [1 5 8 12]

matlab example



How to address local minima?



pfield.m [1 5 8 12]

matlab example

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How can we get out of local minima?

How can we get out of local minima?

Go back to planning.

Wavefront Planning

- Discretize potential field into grid
 - Cells store cost to goal with respect to potential field
 - Computed by Brushfire algorithm (essentially BFS)
- Grid search to find navigation path to goal

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Once start reached, follow brushfire potential to goal

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Example with Local Minima

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	0	ľ	C

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Can we extend potential fields for arm navigation?

Potential Fields for Robot Arm

- Define endeffector goal as the attractive potential with cone potential
- Define repulsive potentials wrt. collision objects
 - Select points on robot links with "bowl" potential from nearest object
- Use manipulator Jacobian to transform potential at each point into velocites at robot joints
- Weighted sum of transformed velocities to generate control

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Navigation Recap

Navigation Recap

Bug X • Complete

- Non-optimal
- Planar

Subsumption and FSMs

- Fast but not adaptive
- Emphasis on good design

Potential Fields

- Complete in special cases
- Non-optimal
- General C-spaces
- Scales w/dimensionality

Grid Search/Wavefront

- Complete
- General C-spaces
- Limited dimensionality

Random walk

• Will find path eventually

Sampling roadmaps/RRT

- Probabilistically complete
- General
- Tractable (with good sampling)
- Scales w/dimensionality
- Not necessarily optimal

Next Lime

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Collision Defection

U.S. Department of Transportation https://www.youtube.com/watch?v=B8Ct5hjs0Jw

