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Genetic Algorithms for Smooth Path Planning

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19. November 2019

Outline

Motivation

Where am I now? Localization.
Where do I want to go? Mapping.
How do I get there? Motion/Path Planning

Path Planning

Position and goal are known -> best way?

Basic conditions:

- Avoid obstacles
- Reduce path length
- Additional features

Major concern:

- Efficiency (Time and energy)
- Safety (Obstacle avoidance)
- Accuracy (Follow path)

Path Planning (continued)

Various categories for PP:

Based on environment:

- Static
- Dynamic

Based on map knowledge:

- Global
- Local

Based on completeness:

- Exact
- Heuristic

Path Planning (continued)

PP problem components:

- Geometry of robot
- Environment
- Degrees of freedom (of robot motion)
- Start and goal configuration

+ simplify search

Define a configuration space:

- Robot mapped as point
- Environment is a 2D plane

Smoothness

Why?

- More natural
- Less problems with overshooting
- Energy and time efficient

Definition:
Trajectory is smooth if its first and second derivative are continuous.

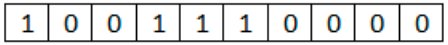
B-Splines for Smoothing

"Splines [...] are functions consisting of pieces of smooth functions glued together in a certain smooth way." A. Kunoth, T. Lyche, G. Sangalli, S. Serra-Capizzano, T. Lyche, C. Manni, and H. Speleers, (2018). "Splines and PDEs: From approximation theory to numerical linear algebra." Cham, Switzerland: Springer, p. 1

- Piecewise polynomials
- Globally smooth
- More flexible than regular interpolation through piecewise definition
- Connection points are called knots
- Powerful (for computer-aided geometry)

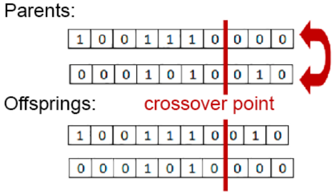
Genetic Algorithms

- Population of solutions
- Chromosome



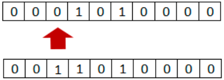
- Gene

- Initialization
- Parent Selection
- Recombination (Crossover)



Genetic Algorithms (continued)

- Mutation



- Fitness function
- Survivor selection
- Stopping criterion

Probabilistic Roadmaps vs. GAs for PP

	PRM	GA
Environment	Free configuration space	Discretized or continuous configuration space
Initialising way	Generate random configurations Build roadmap R by interconnecting configurations locally Connect initial and goal configuration to R	Create chromosomes from random grid cells First gene is start Last gene is goal
Finding way	Search edges of R for continuous path from initial to goal config.	Perform genetic algorithm Evaluate fitness function based on pathlength

Probabilistic Roadmaps vs. GAs for PP (continued)

	PRM	GA
Pros	Probabilistic complete Easy to implement Computationally cheap	Always reach (near) global optimum Don't get stuck in local optima Explore while preserving best Simultaneous search For continuous or discrete config. space Good performance in complex environment Versatile
Cons		Computationally expensive Tuning necessary

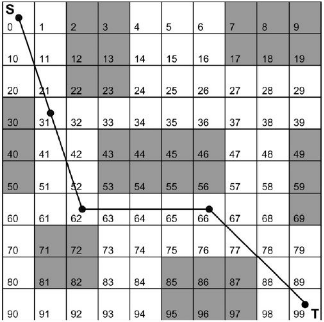
GAs for Smooth PP

Instead of smoothing a path afterwards (e.g. with B-Splines), we generate a smooth path.

	Regular GA	Bézier GA
Generate	way points	Bézier control points
Path	connected way points	Bézier curve
Fitness function	length of way	length of Bézier curve
Obstacles	collide when point or part of path between two points intersects	collide when Bézier curve intersects

GAs for Smooth PP (continued)

Regular GA:

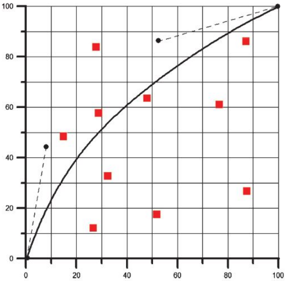


Source: A. Tuncer and M. Yildirim (2012) "Dynamic path planning of mobile robots with improved genetic algorithm" in Computers and Electrical Engineering,

- Increases computation

Vol. 38, pp. 1564–1572

GA with Bézier:



Source: M. Elhoseny, A. Shehab and X. Yuan (2017) "Optimizing robot path in dynamic environments using Genetic Algorithm and Bezier Curve", in Journal of Intelligent and Fuzzy Systems, Vol. 33, pp. 2305–2316

Conclusion and Outlook

Conclusion:

- PRMs are simple and sufficient
- Together with B-splines it can produce smooth paths
- GAs are powerful tools for finding (near) optimal path in a complex environment
- Incorpoarted with Bézier curve promising for smooth path generation

Outlook:

- Investigate possible problems of GAs for Smooth PP
- Is the extra effort worth it?

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