Real Path Planning based on Genetic Algorithm and Voronoi Diagrams

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Overview

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Teleoperation

The man has the control.

- A solution for a history moment.
- After that ...
    - Human dependence.
    - Cognitive fatigue.
    - Comunication delay.
    - Broken pipe.
    - Others.

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Autonomy and Intelligence

Can the machines take control?

- Autonomy
  - “A robotic agent ability to perform a set of tasks in a given environment without the need of human intervention to achieve their objectives”. [1]
  - Depending on the environment nature the agent may or may not require "intelligence".
- Intelligence
  - “Capability that allows an entity or agent to function properly in a given environment”. [1]
  - A high degree of intelligence would allow the agent to adapt to a wider range of environments.
  - It is important to remember that the physical constraints limit the ability to adapt.

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Environments
The robot like a situated agent.

The environments can be classified according to the following dimensions or perspectives [2]:

- Completely or partially observable.
- Deterministic or stochastic.
- Sequential or episodic.
- Dynamic or static.
- Discrete or continuous.
- Mono or multi agent.

Motion planning

How to move in a dynamic and unknown world?

The least one can expect from an autonomous robot is to have the ability to plan their own movements. [3]

- How to achieve a target destination?
  - Navigation.
- Where I am?
  - Localization.
- Where have I been?
  - Mapping.

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Approaches

Resolution methods [3]

- Roadmap
  - Consists in capturing the connectivity of free space on a network of roads.
- Cell Decomposition
  - Possibly the most studied family of methods.
  - Consist of decomposing the free space into cells. It assumes that the intra-cell navigation is easy to solve and build a graph to represent inter-cell connectivity.
- Potential Field
  - It consists of discretizing the entire configuration space using a regular grid of small cells.
  - Then move the robot assuming that in each cell it is a particle under different artificial potential fields.

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Path planning

Three parts of a single problem.

- Path planning.
  - Solve a free path between the initial state in which the robot is and a destination state under certain evaluation criteria.
  - The most used are:
    - Distance, Security, Energy consumption, Softness.
- Trajectory planning.
  - Takes into account the time variable.
  - Low level control.
    - Resolves monitoring and following of predetermined paths in the previous steps.

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- Highway visibility: Construction of maps from trajectories Voronoi diagrams using certain optimization criteria. [4]
- Path Planning based on AG: From a representation of the environment called Digital Potential Fields, apply a GA to improve the length, safety and smoothness of the paths. [5]

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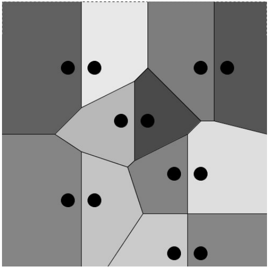
Voronoi Diagrams

Two properties of interest in the context of path planning for mobile robots:



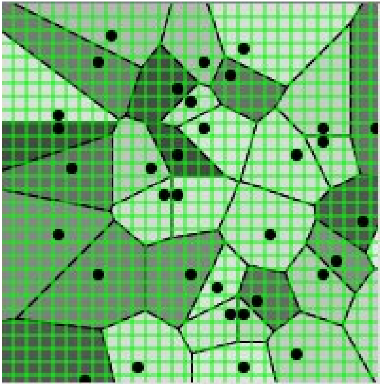
1. Every Voronoi edge belongs to the bisector of the line segment formed by the two generating points of the regions that determine the edge.
2. Every Voronoi vertex is located exactly in the center of the circle whose perimeter generating points are the regions that determine the vertex.

Overview

1. Motivation
   - Background
   - Introduction
   - The path planning problem
   - Previous work
2. Our proposal
   - Implementation
   - Results

World model

- Completelly observable, static, deterministic, sequential, discrete and single-agent .
- Regular grid, free cells or obstacles.
- Voronoi diagram generated by the set of obstacles.
- Particle like Robot. [6]



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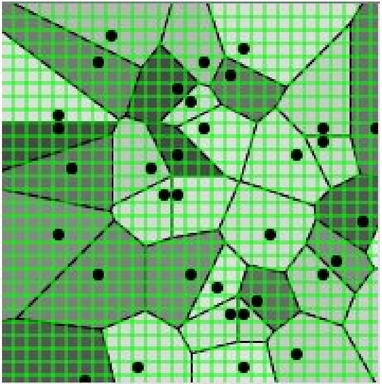

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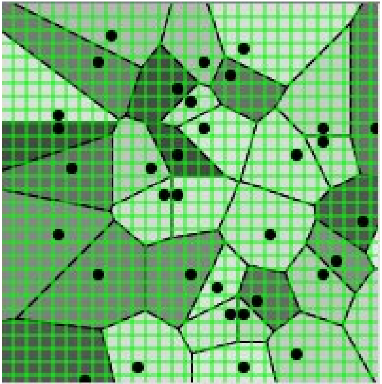

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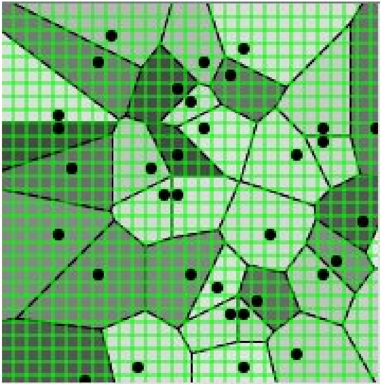

GA application I

- Chromosomes: each path is encoded as a sequence of free cells of variable length.
- Initial population:
  - Generate the DV from obstacles in the environment.
  - Identify the regions that contain the start and end position.
  - Dijsktra for all combinations of points of departure and arrival.
  - Randomly selection of paths and cells.
- *Fitness* function:
  - Feasible, length, smoothness and security.
  - Infeasible: length, rate and degree of infeasibility.

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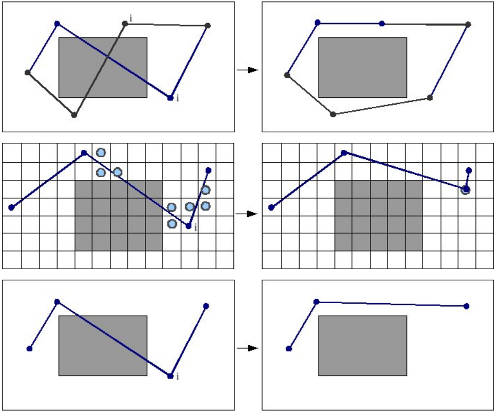
GA application II

- Genetic Operators:



Platform I

Simulated	CPU	Intel Pentium Dual Core E2140 - 1.60GHz
	RAM	2GB DDR
	Swap	3GB
	Disk	160 GB
Real	Arena	1680x1680mm square area over a FIRA Mirosot field
	Vision	Doraemon
	Robot	KheperaIII + KoreBot II

Cuadro: Hardware platform.

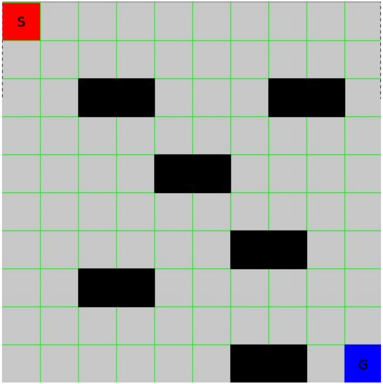
Platform II

OS	GNU/Linux - Xubuntu 2.6.31-22
IDE	Eclipse Helios 3.6
Language	Java 1.6
AG Library	JGAP 3.3.3
Graph Library	JGrapht 0.8.1
Voronoi Library	Quickhull3d 1.4
Viewer	Processing 1.0.7

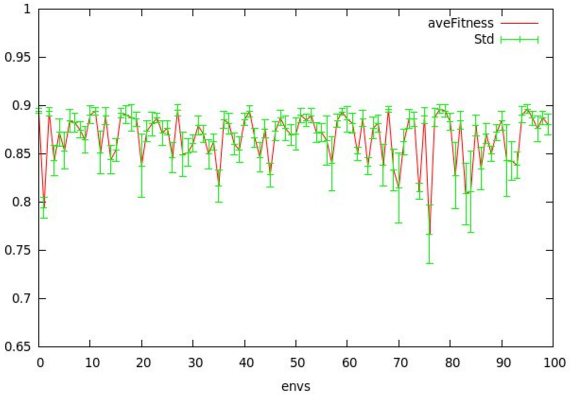
Cuadro: Software platform.

Overview

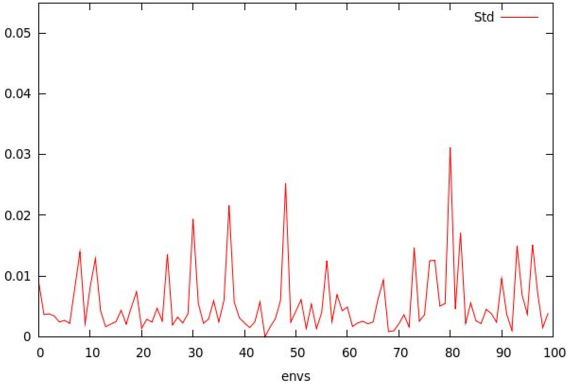
Test environment



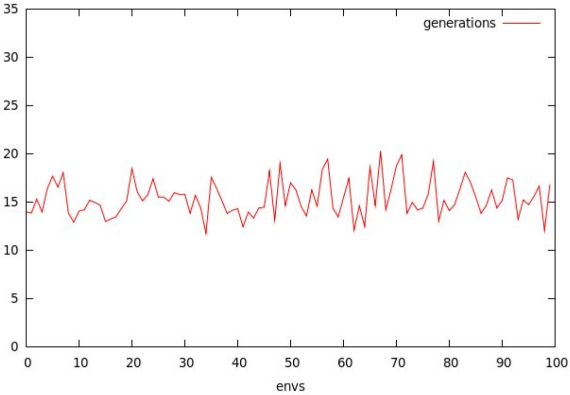
Fitness


1
0.95
0.9
0.85
0.8
0.75
0.7
0.65
0
10
20
30
40
50
60
70
80
90
100
envs
aveFitness
Std

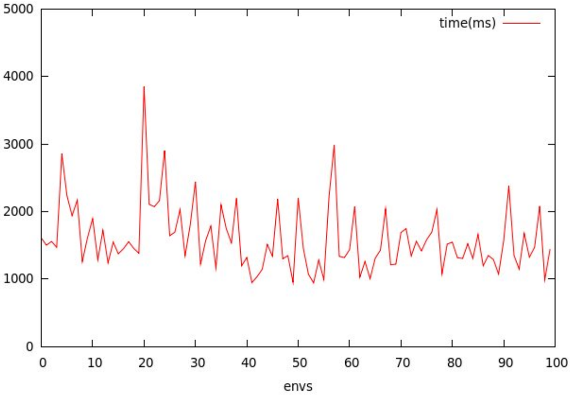
Standard deviation



Generations



Time


time(ms)
5000
4000
3000
2000
1000
0
0
10
20
30
40
50
60
70
80
90
100
envs

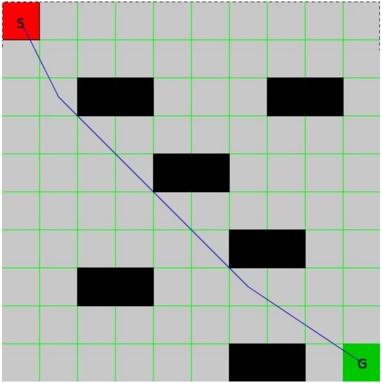
Numerical comparison I

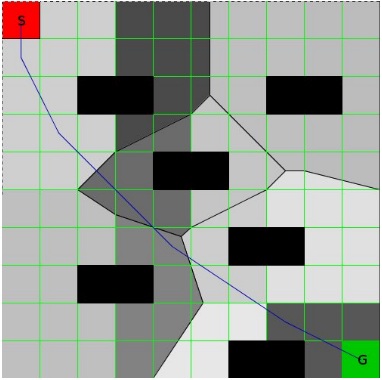
	GA over DPF	GA over VD
Environment generation (ms)	1632	1217
GA Evolution time (ms)	275.79	1299
Average number of generations	12.51	17.09
Average *Fitness*	0.82990	0.84669
Standard deviation	0.01067	0.00567
Best *Fitness*	0.84583	0.85459
Deviation from the fittest	0.01267	0.00790
Average length	656.27	657.63
Average safety	253.58	280.46
Average smoothness	0.29111	0.21318

Numerical comparison II

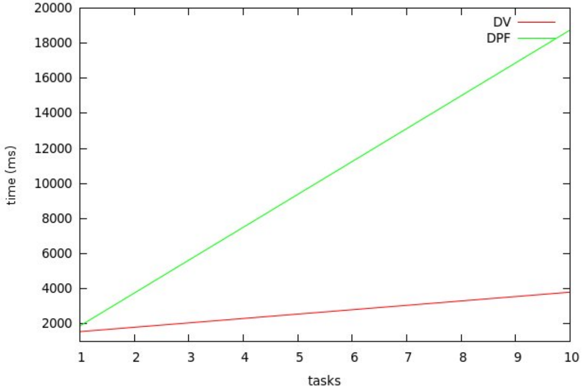
AG over DV	Parameters of DPF	Parameters ad-hoc
Environment generation (ms)	1305	1136
GA Evolution time (ms)	223	265
Average number of generations	15	15.45
Average *Fitness*	0.83437	0.83720
Standard deviation	0.01376	0.01169
Best *Fitness*	0.85433	0.85433
Deviation from the fittest	0.01996	0.01714
Average length	662.44	661.07
Average safety	291.19	287.55
Average smoothness	0.29058	0.27583

Visual comparison





Multiple tasks execution time



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- Feasibility from the methodological point of view and in practical applications with real robots.
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Future works

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- Consider the dynamic aspect.

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- Co-Authors
    - Gonzalo Tejera
    - Martín Pedemonte
    - Serrana Casella
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