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Evolutionary Artificial Potential Field for Path Planning: A GPU Implementation

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Outline

- Introduction
- Evolutionary Artificial Potential Field
- GPU Implementation
- Results
- Conclusions and Future Work

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Motivation

- Robotics is one of the most important technologies since it is a fundamental part in automation and manufacturing process.
- In particular, there is an increasing demand of autonomous mobile robots in various field of application.

http://blogs.nvidia.com/blog/2014/01/07/audi-will-deploy-tegra-k1-to-power-piloted-driving-initiatives/
http://www.nasa.gov/centers/goddard/news/features/2012/msl-post-landing_prt.htm.
http://www.canada.com/technology/futuretech/Self+driving+cars+almost+here+expect+tomorrow/6806156/story.html

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Problem

- This work addresses the problem of autonomous navigation of a mobile robot to take it from one position to another one without the assistance of a human operator, in particular, **planning** a reachable set of mobile robot configurations to accomplish its mission.
- **Path planning** of a mobile robot is to determine a collision-free path from a starting point to a goal point **optimizing a performance criterion** such as distance, time or energy, distance being the most commonly adopted criterion.

http://www.mobilerobots.com/ResearchRobots/P3AT.aspx

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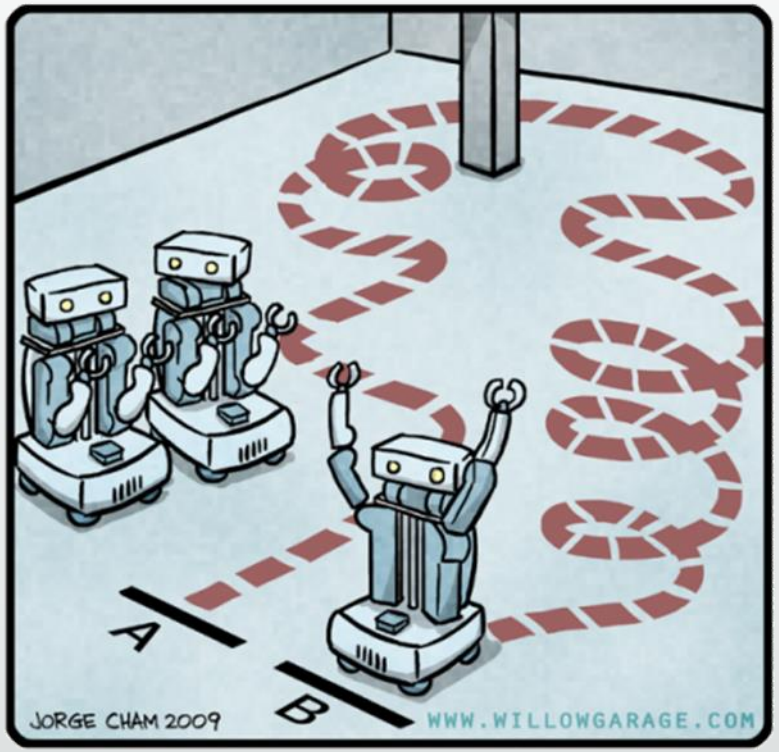
Research objective

- The main objective is to design and develop an efficient path planning algorithm, that it is capable to find an optimal collision free path in a **reasonable time** to take the robot from the start to the goal point, considering static and dynamic environments with obstacles.



"HIS PATH-PLANNING MAY BE SUB-OPTIMAL, BUT IT'S GOT FLAIR."

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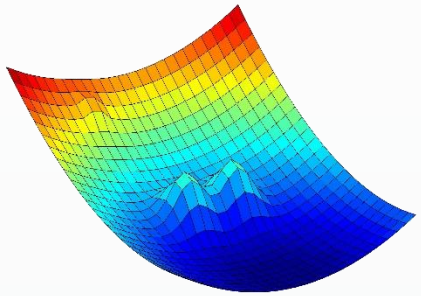
Literature review

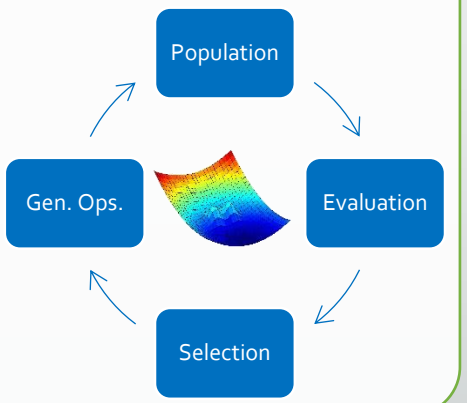
Artificial Potential Field (APF)

Khatib (1986) proposed the APF, this approach is based on two potential field (attractive + repulsive) to drive the robot to its goal.



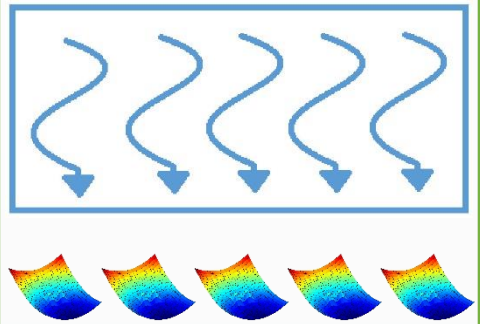
Evolutionary Artificial Potential Field (EAPF)

Vadakkepat et al. (2000) proposed Evolutionary APF (EAPF) to derive optimal potential field functions using GAs.



Parallel Evolutionary Artificial Potential Field (PEAPF)

Montiel et al. (2014) proposed the Parallel EAPF algorithm using the CPU threads to accelerate the fitness function evaluation.



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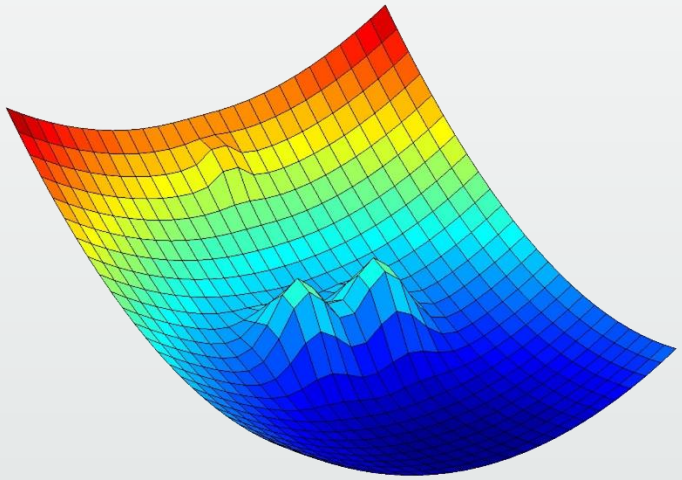
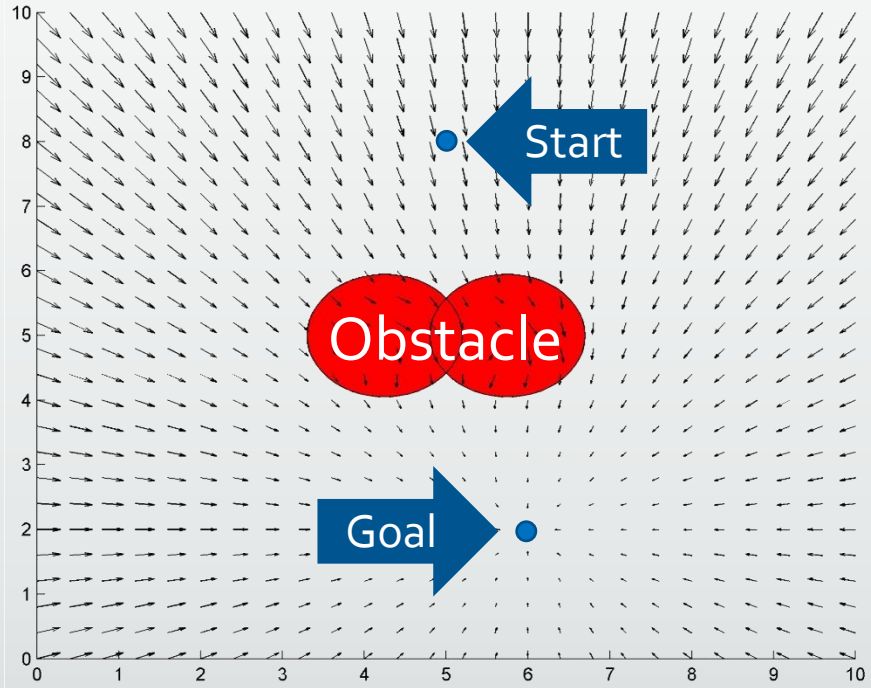
Artificial Potential Field

Potential Surface



Potential Area



Total potential field

$$U(q)_{total} = U(q)_{att} + U(q)_{rep}$$

Attraction potential field

$$U(q)_{att} = \frac{1}{2} k_a (q - q_f)^2$$

Repulsive potential field

$$U(q)_{rep} = \begin{cases} \frac{1}{2} k_r \left(\frac{1}{\rho} - \frac{1}{\rho_0} \right)^2 & if\ \rho \leq \rho_0 \\ 0 & if\ \rho > \rho_0 \end{cases}$$

Total force

$$F(q) = -\nabla U(q)_{total}$$

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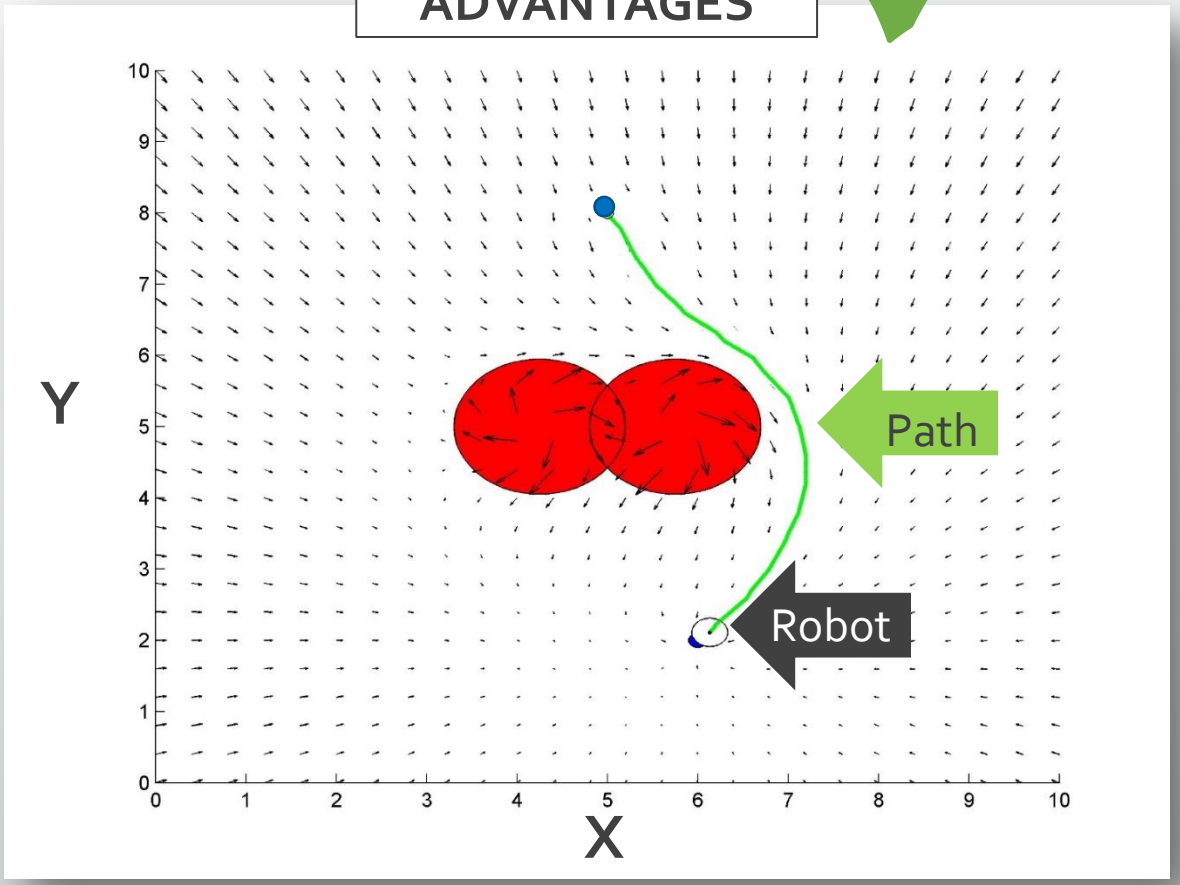
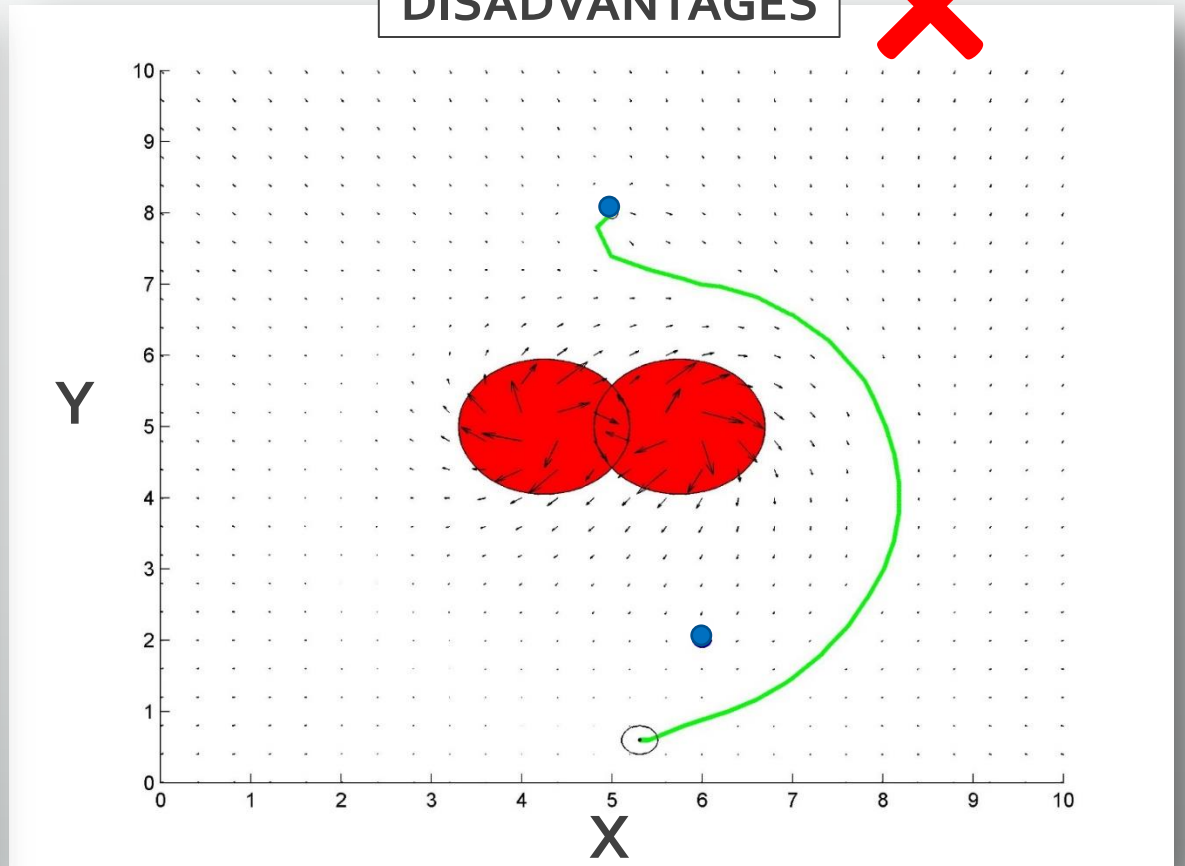
Artificial Potential Field

ADVANTAGES



DISADVANTAGES



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Evolutionary Artificial Potential Field

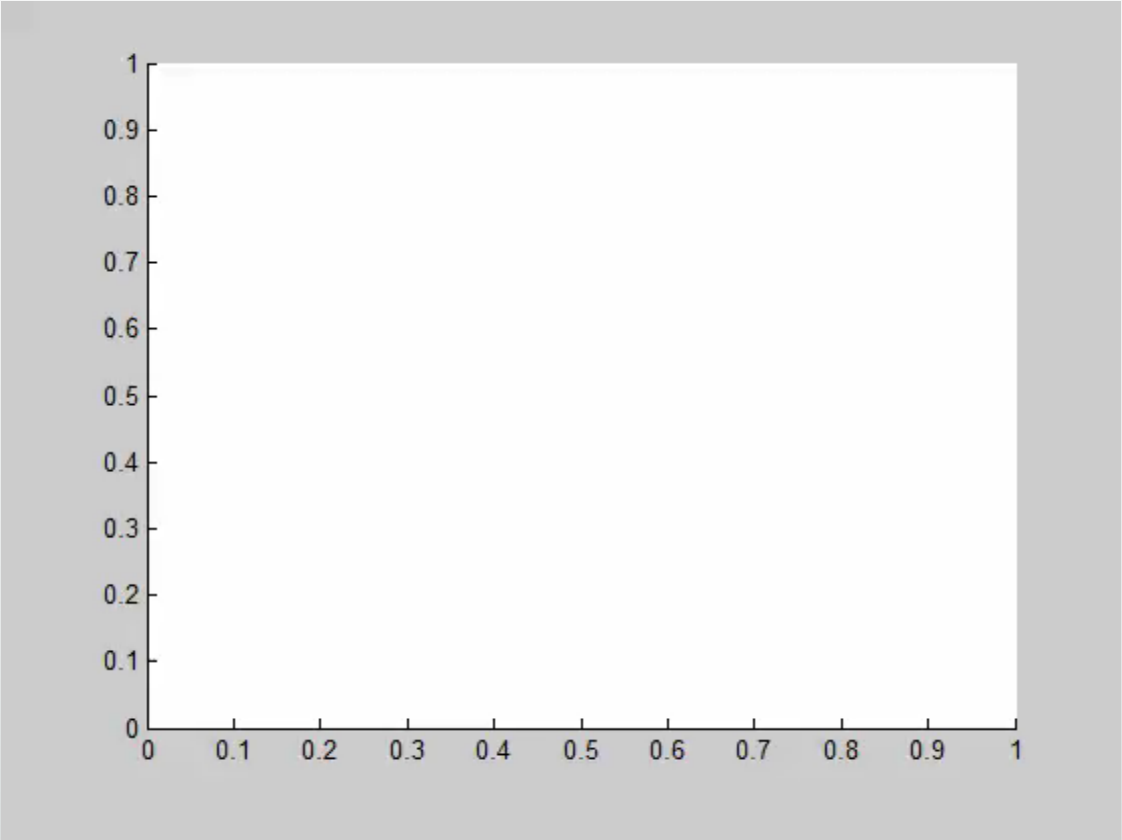
Population (chromosomes)

Evaluation (fitness)

Selection (mating pool)

Genetic operators

Genetic Algorithms (GAs) are adaptive heuristic search algorithm premised on the evolutionary ideas of natural selection and genetic. The basic concept of GAs is designed to simulate processes in natural systems necessary for evolution.



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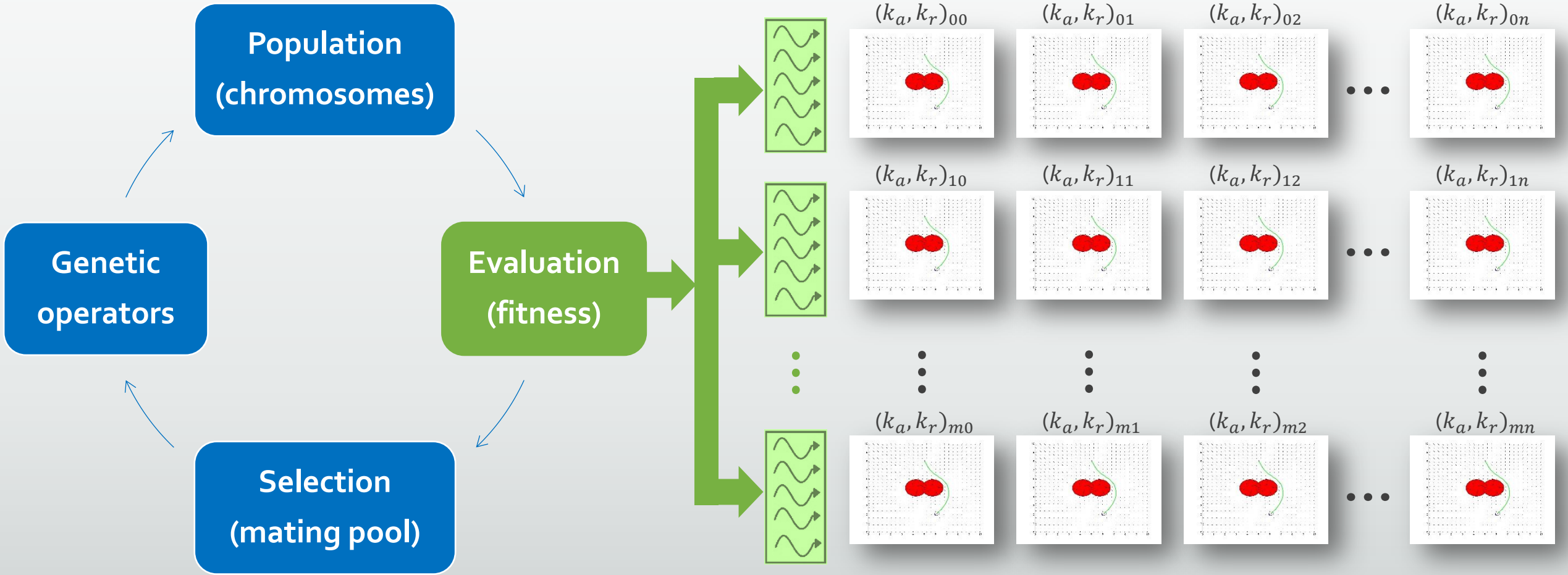
Parallel Evolutionary Artificial Potential Field



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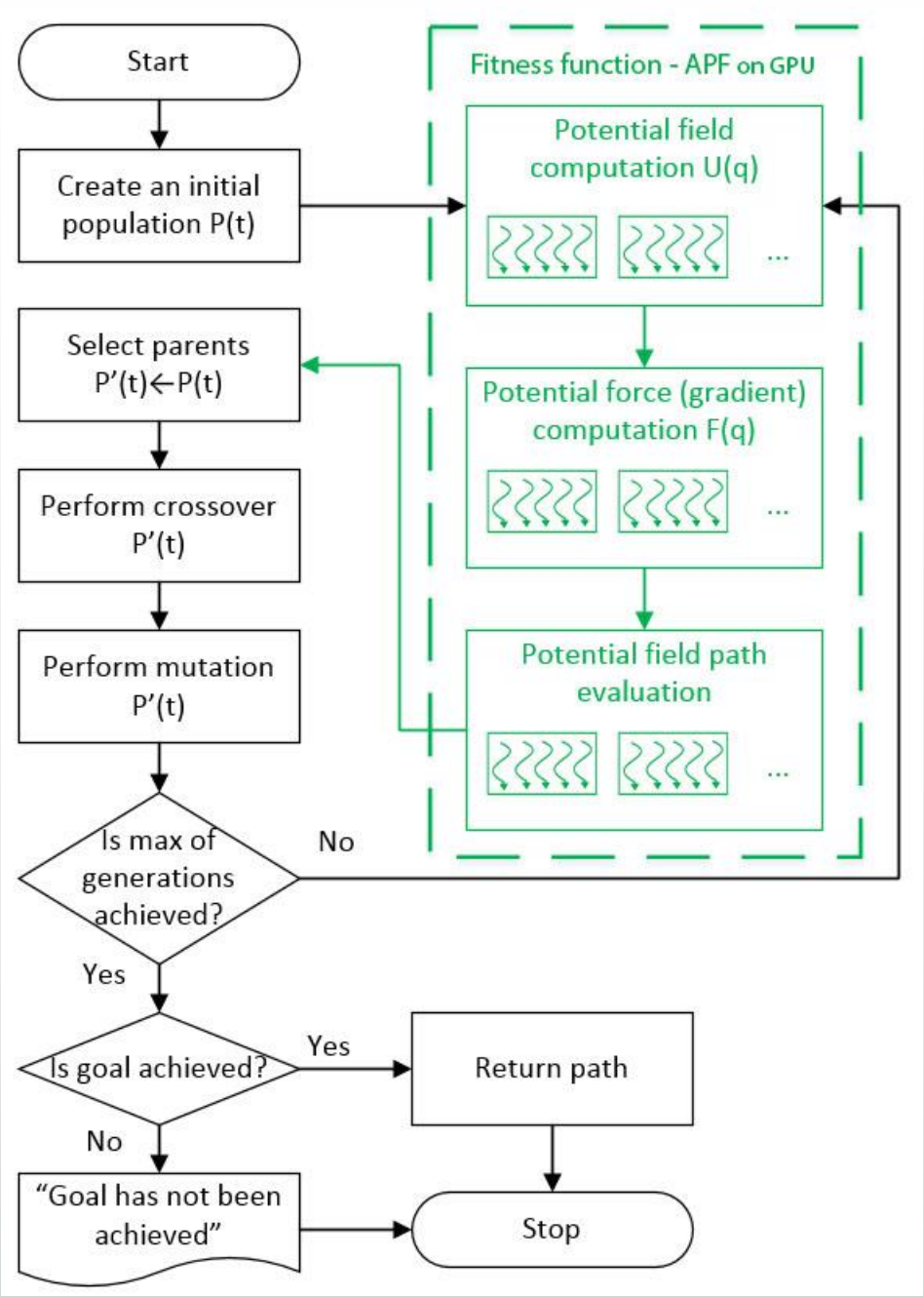

GPU Implementation

- The APF is blended with an Evolutionary Algorithm
- The potential functions are implemented in GPU (parallel)
  - Potential field
  - Potential force
  - Path evaluation
- The genetic operators are implemented in the CPU (sequential)
  - Selection
  - Crossover
  - Mutation
- The path planning system was implemented with Matlab and CUDA programming platforms

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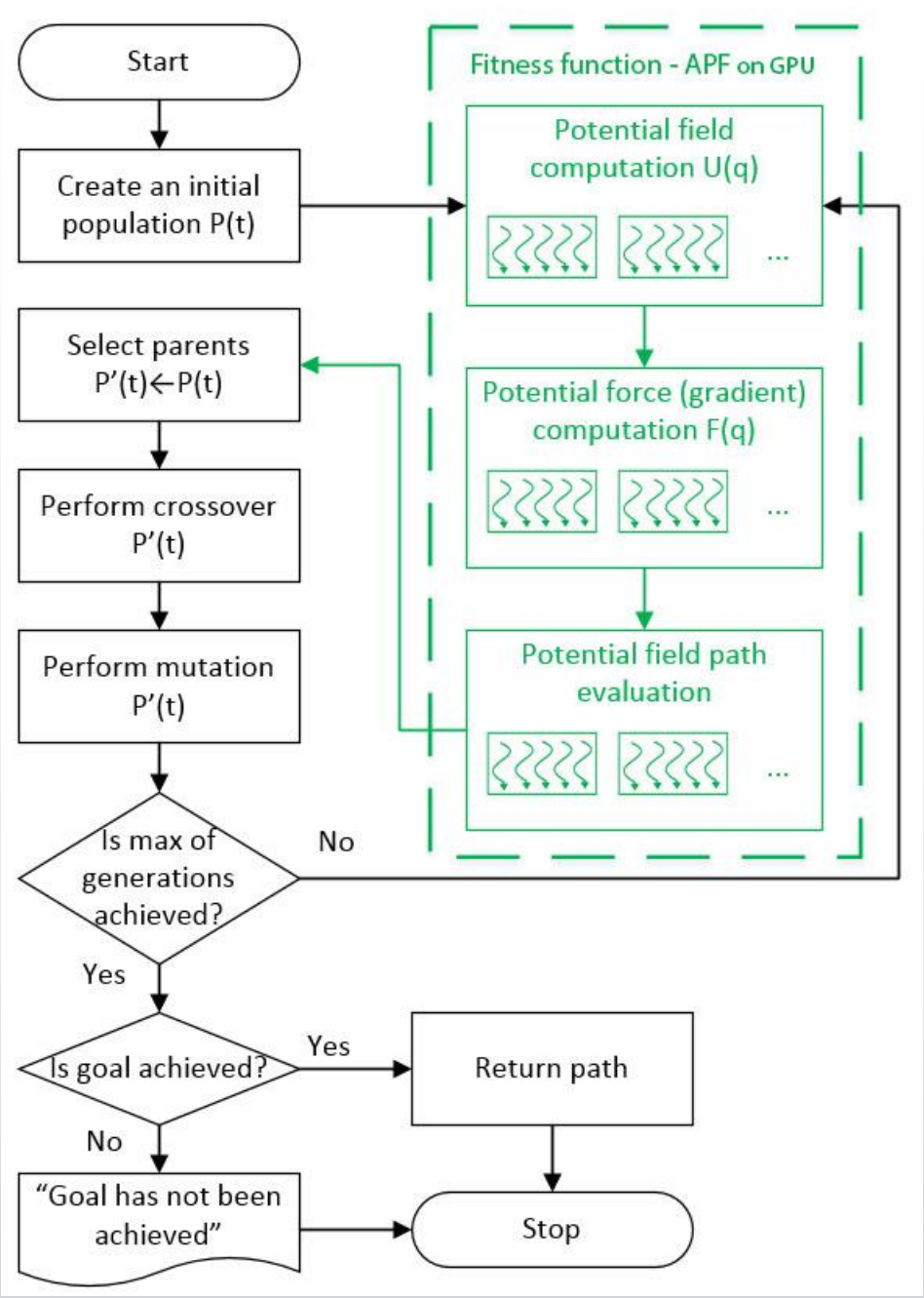
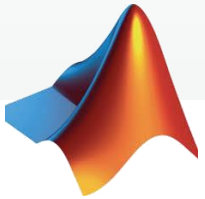


Host – Matlab call CUDA

eapf.m



```
% Create CUDAKernel object
kernel_APF_Potential =
parallel.gpu.CUDAKernel('apf_gpu_eval.ptx',...
                        'apf_gpu_eval.cu', 'APF_Potential');

% Set object properties
kernel_APF_Potential.GridSize = [gridSize, 1, 1];
kernel_APF_Potential.ThreadBlockSize = [blockSize, 1, 1];

% Call feval with defined inputs
[dev_Ua, dev_Ur, ...] = feval(kernel_APF_Potential, ...);

% Collect data
Ua = gather(dev_Ua);
Ur = gather(dev_Ur);
.
.
.
```

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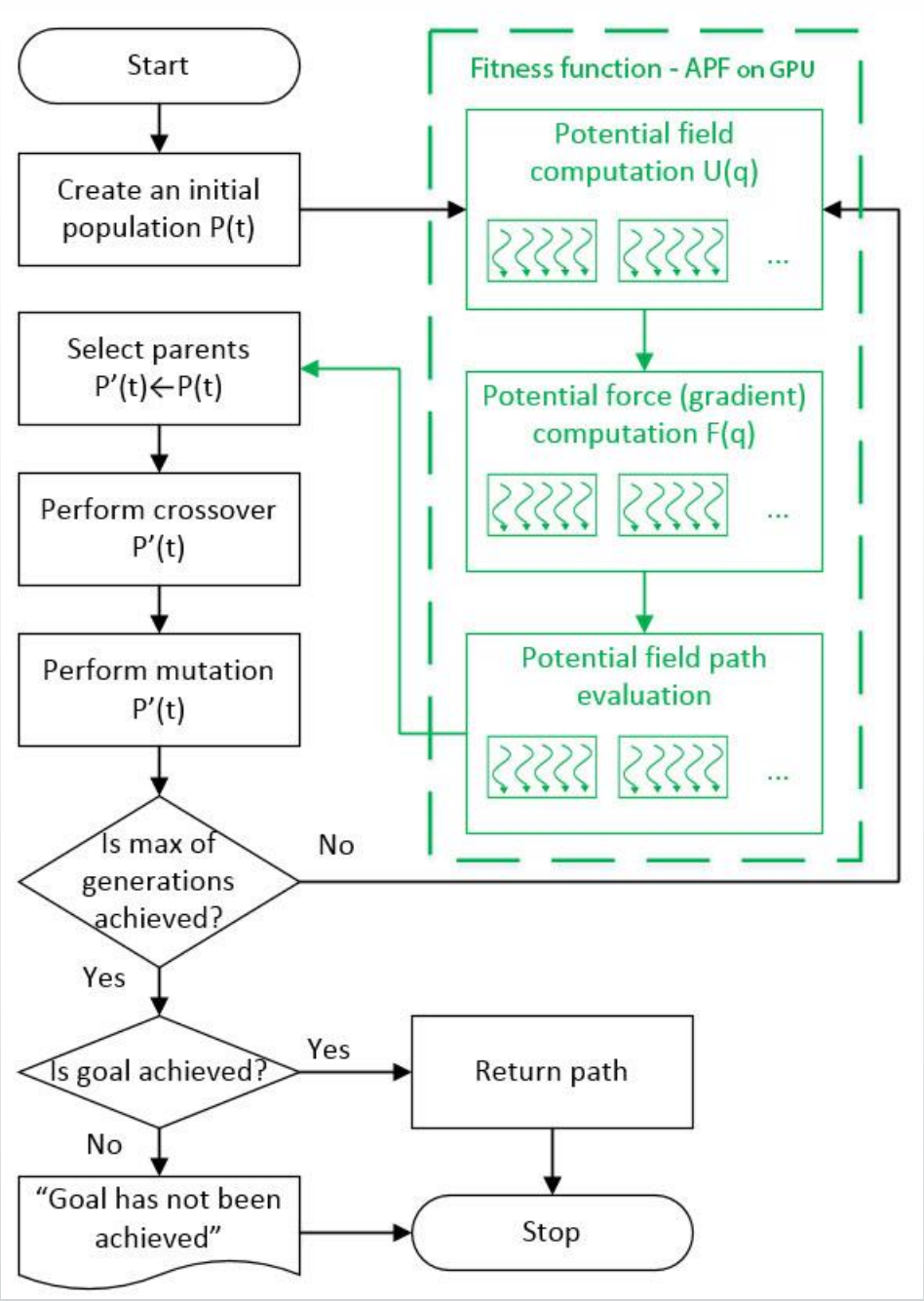

Device – CUDA kernel

apf_gpu_eval.cu

```
// CUDA kernel for potential field computation
__global__ void APF_Potential(float *Ua, float *Ur, ...)
{
        int id = blockIdx.x * blockDim.x + threadIdx.x;
        .
        .
        .

}
```

Potential field	Potential force	Evaluation
$U(q)_{total} = \frac{1}{2}k_a(q-q_f)^2 + \frac{1}{2}k_r\left(\frac{1}{\rho}-\frac{1}{\rho_0}\right)^2$	$F(q) = -\nabla U(q)_{total}$	$S = \sum_{i=0}^{n}(q_{i+1}^2 - q_i^2)^{1/2}$

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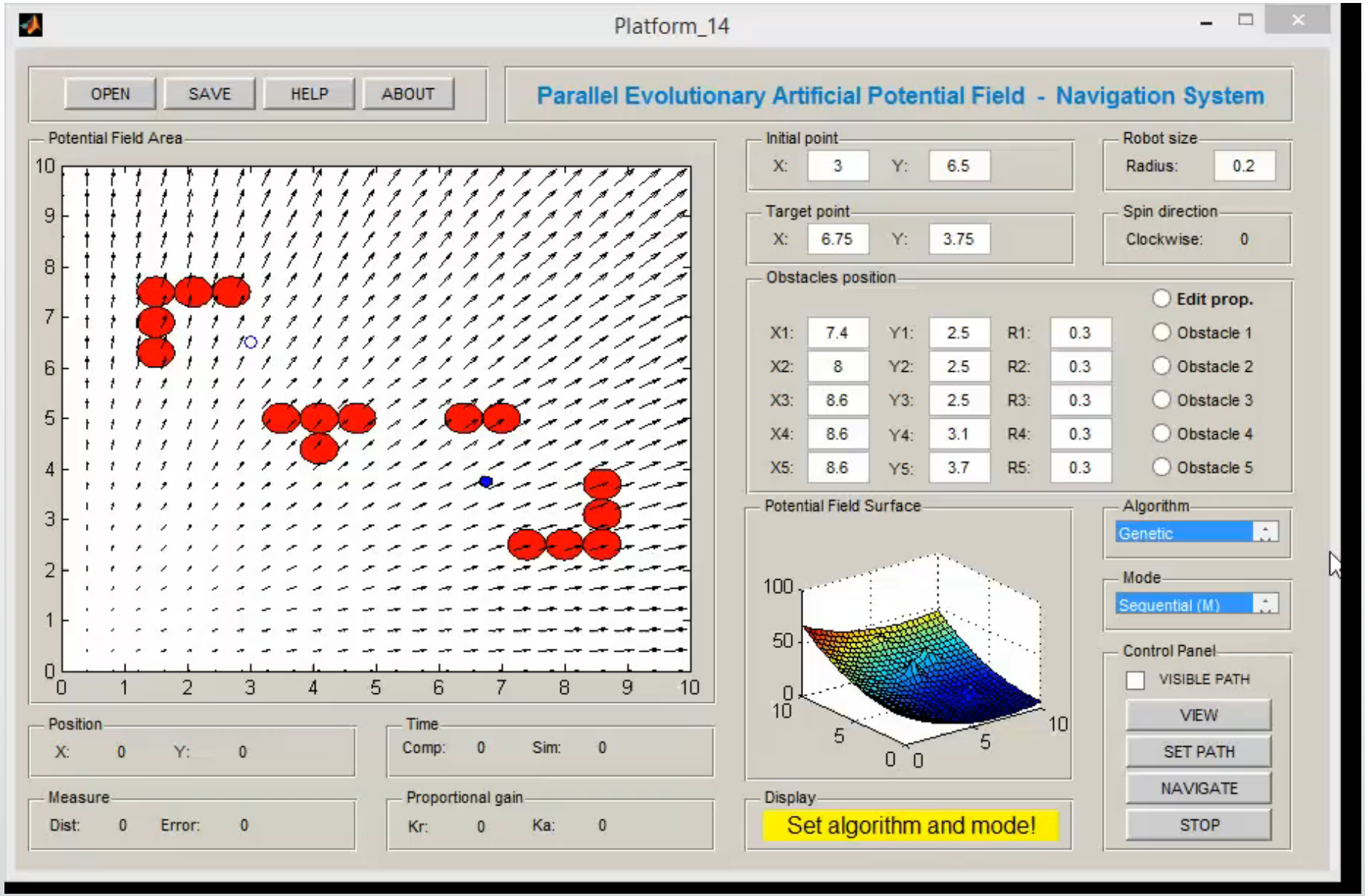
Results: off-line path planning



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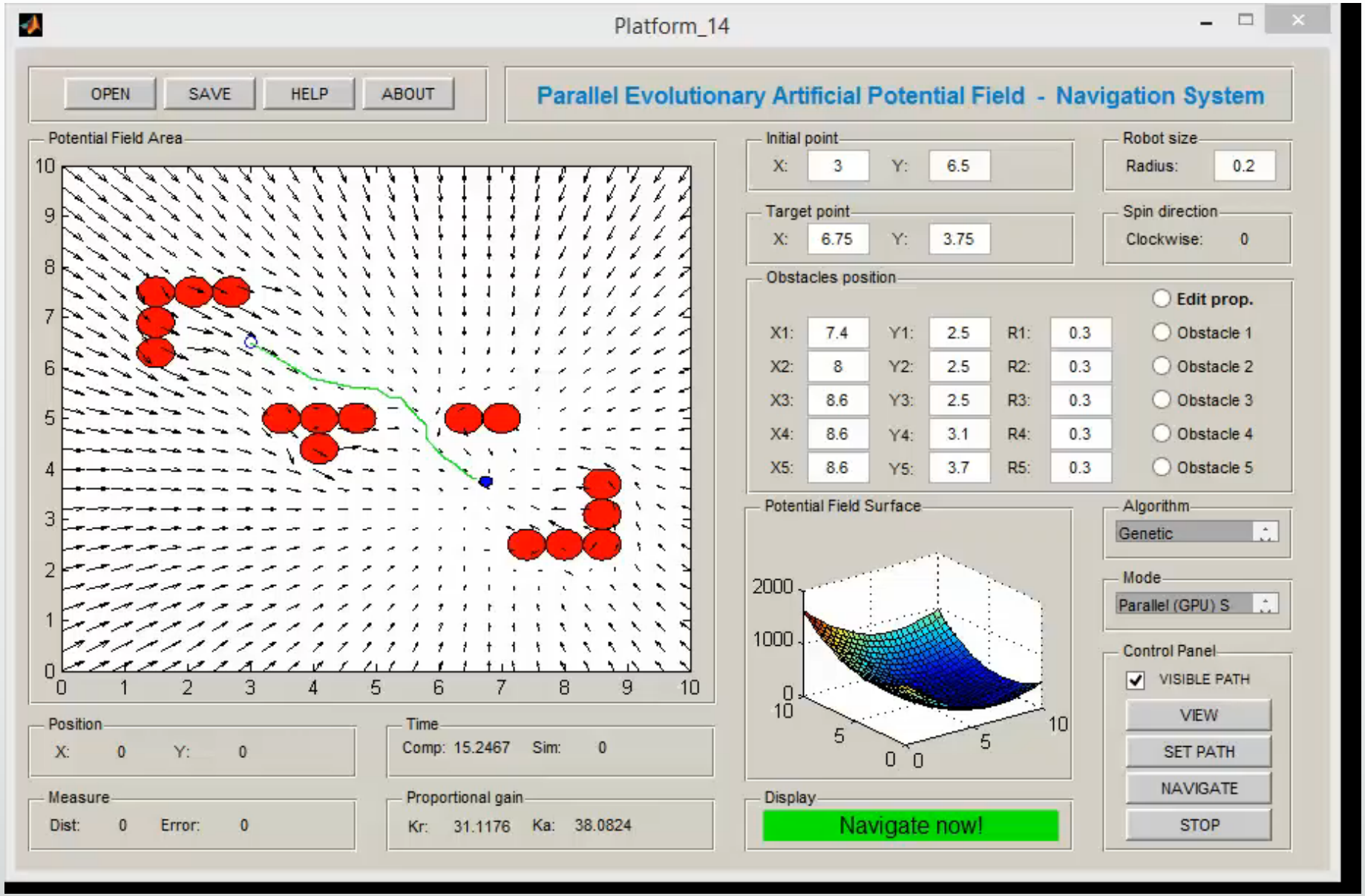
Results: on-line path planning



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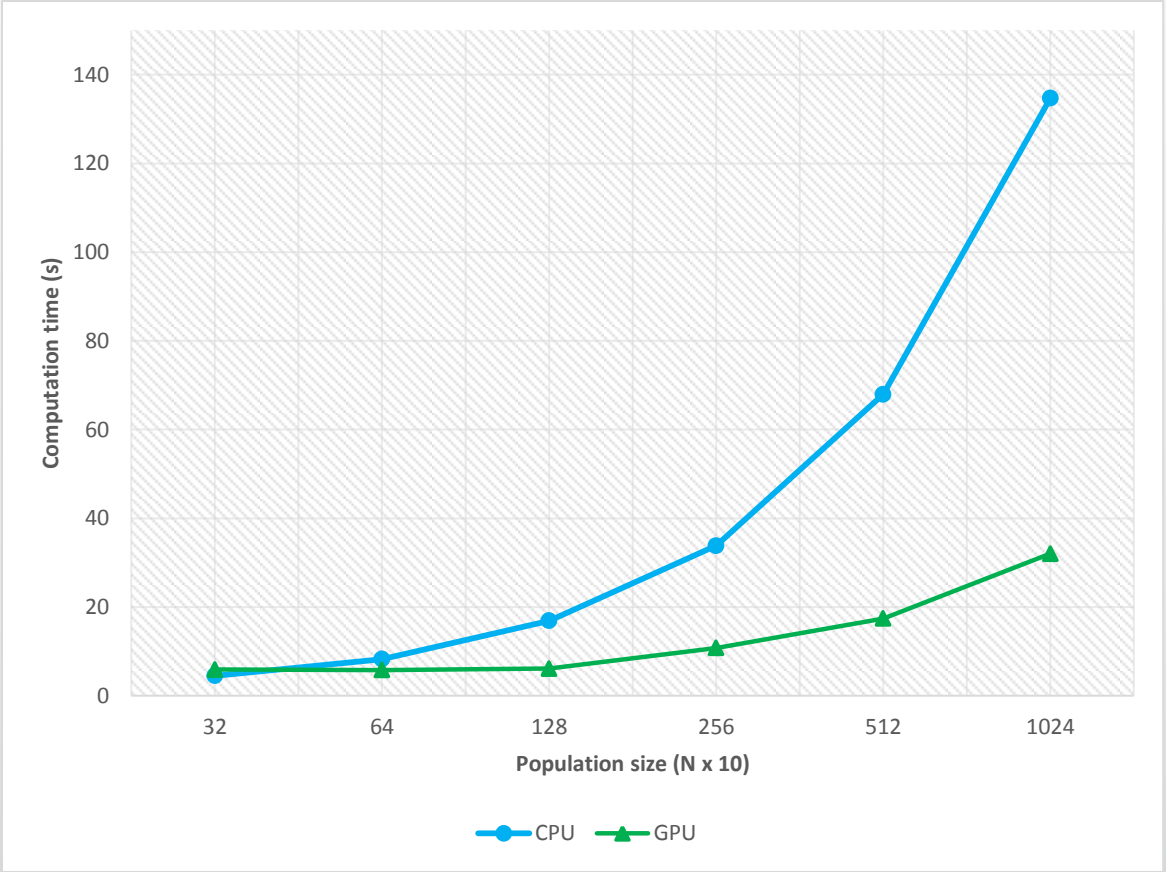
EAPF computation time results

- In EAPF the solution quality improves with larger populations.
- The experimental results show a speedup of 4.2 on GPU implementation.

	CPU (sequential)		GPU (parallel)		
	Intel Core i7-4710HQ CPU @ 2.50Ghz		GeForce GTX 860M		
Population size (N x 10)	Mean (μ) seconds	Std. Dev. (σ)	Mean (μ) seconds	Std. Dev. (σ)	Speedup
32	4.491	1.128	5.902	0.985	0.8
64	8.255	0.770	5.784	0.068	1.4
128	16.895	1.165	6.120	0.033	2.8
256	33.832	1.478	10.762	0.230	3.1
512	67.957	2.430	17.402	0.257	3.9
1024	134.701	3.548	32.003	0.528	4.2



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Conclusions

- Through the integration of the APF with GAs using parallel computing, it has been presented a path planning system capable of obtaining good solutions (even the global optimum) in a moderate run time.
- It has been demonstrated that parallel EAPF on GPU is capable to solve the path planning for off-line and on-line cases.
- Due to the simulation results, it can be concluded that parallel EAPF on GPU can be capable of facing more complex and bigger planning problems.

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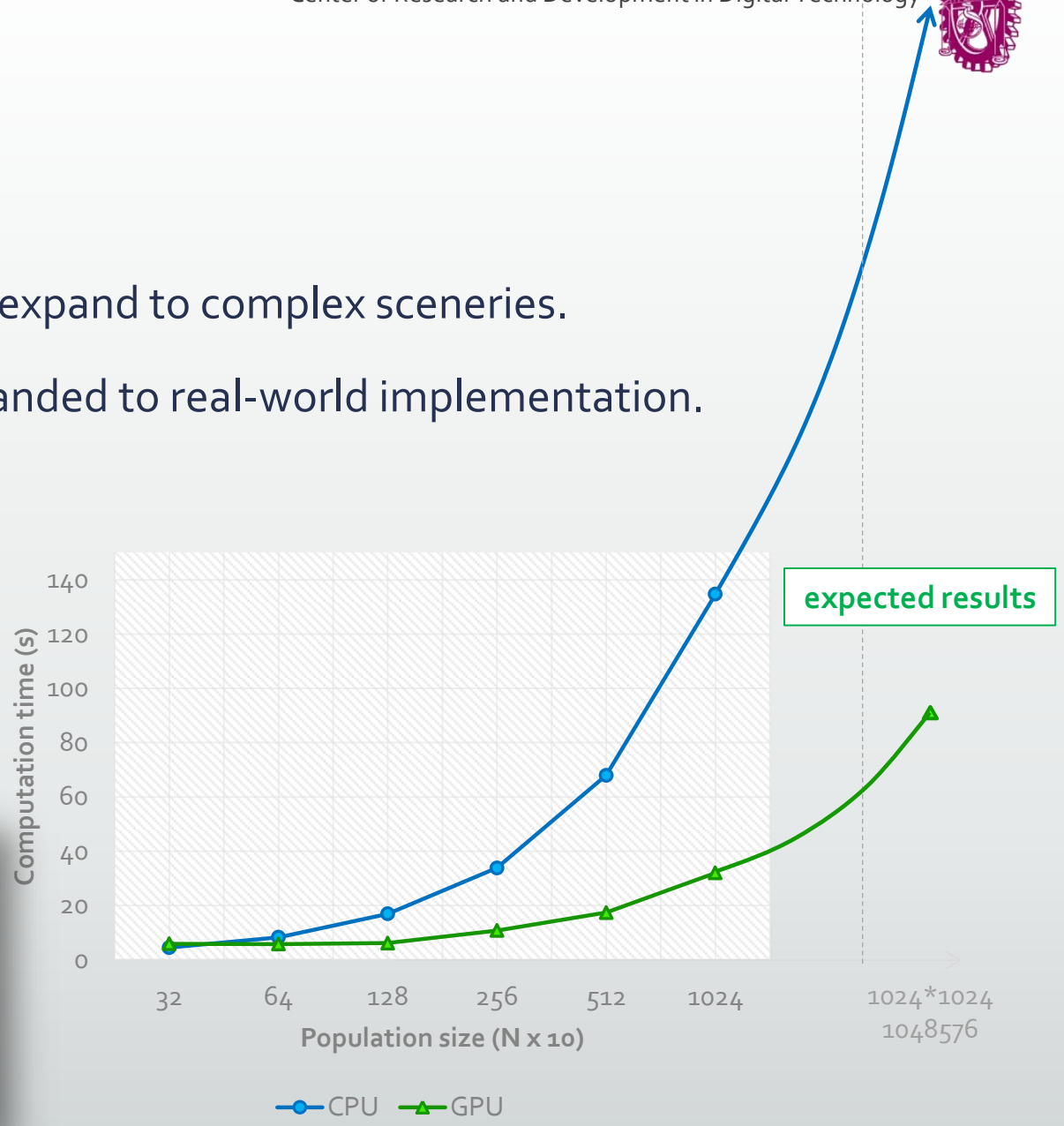
Future work

- In the future, the work will be expand to complex sceneries.
- The approach will also be expanded to real-world implementation.

http://www.futura-sciences.com/magazines/high-tech/infos/actu/d/robotique-robots
http://www.dailygalaxy.com/my_weblog/2012/02/newsflash
http://www.darpa.mil/newsevents/releases/2014/03/13.aspx



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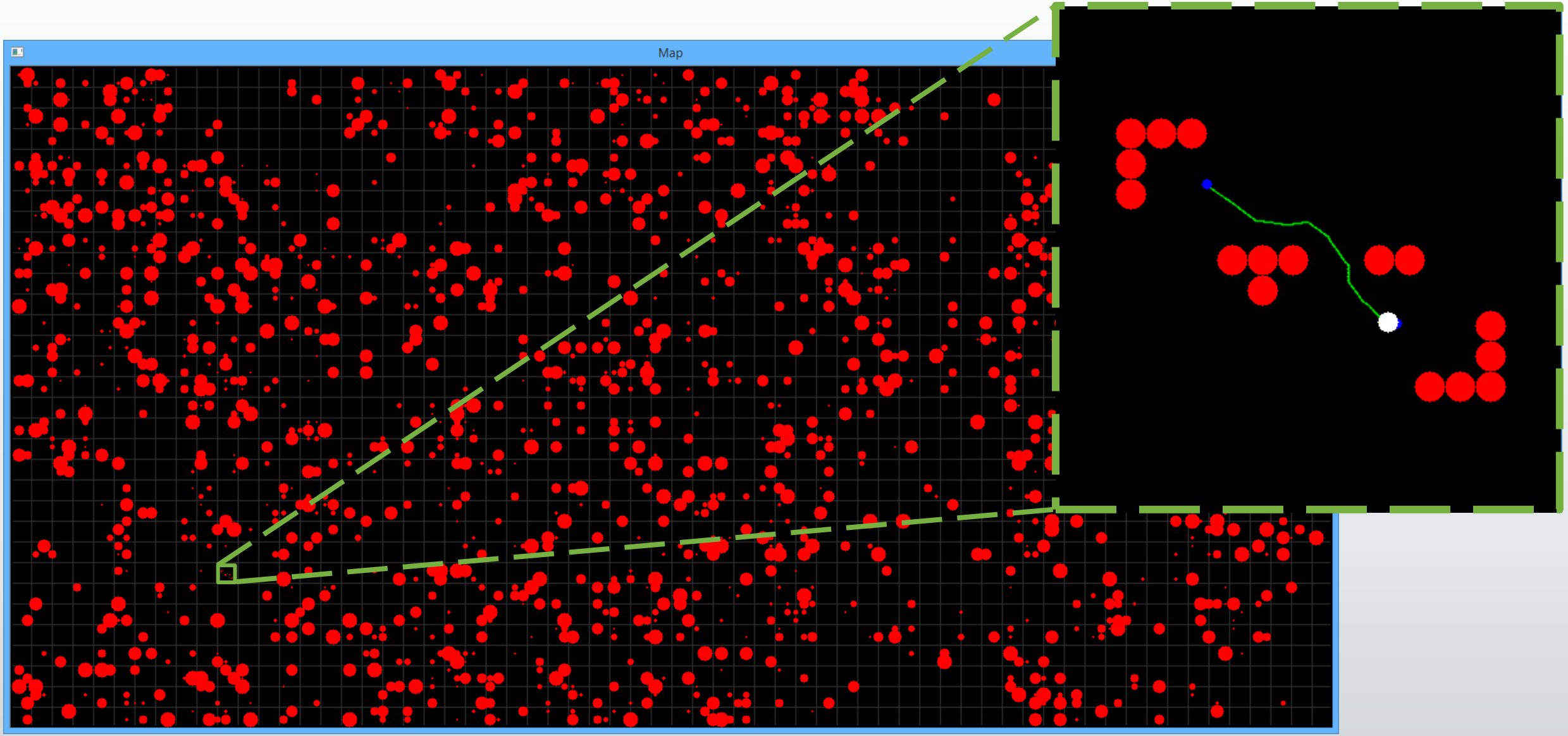

Acknowledgments

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Thanks for attending!

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