GENERATIVE ADVERSARIAL NETWORK BASED HEURISTICS FOR SAMPLING–BASED PATH PLANNING

Azamat Kanametov, Alina Kolesnikova, Timofey Zinenko

April 15, 2021

MIPT

Outline

PROBLEM STATEMENT

Problem statement

Given:

- $\mathcal{X} \in \mathbb{R}^n$ – the state space, $n \in \mathbb{N}^n$, $n \geqslant 2$
- $\mathcal{X}_{obs}$ – obstacle space, $\mathcal{X}_{free} = \mathcal{X} \setminus \mathcal{X}_{obs}$ – free space
- $x_{init} \in \mathcal{X}_{free}$ – the initial state, $x_{goal} \in \mathcal{X}_{free}$ – the goal state
- $\mathcal{X}_{goal} = \left\{ x \in \mathcal{X}_{obs} \middle| \left\| x - x_{goal} \right\| < r \right\}$ – the goal region
- Σ – the set of all feasible paths
- $c(\sigma)$ – the cost function, $\sigma \in \Sigma$,

$$Cost(x_i, x_j) = \left\| x_i - x_j \right\|, \quad x_i, x_j \in \mathcal{X}_{free}$$

Find: feasible path $\sigma^* : [0, 1] \to \mathcal{X}_{free}$

$$\sigma^* = \underset{\sigma \in \Sigma}{\arg\min}\, c(\sigma), \quad s.t.\ \sigma(0) = x_{init}, \sigma(1) \in \mathcal{X}_{goal}$$

APPROACH

Background & Idea

Background

- Sampling–based algorithms solve path planning problems through constructing space–filling trees to search a path σ.
- The tree is built incrementally with samples drawn randomly from the free space $\mathcal{X}_{free}$
- Drawbacks: the quality of initial solution, the convergence speed

Idea

- Use generative adversarial network (GAN) to learn promising regions and construct heuristic non–uniform sampling distribution $\mathcal{X}_H \subset \mathcal{X}_{free}$ to reduce sampling space
- Use this heuristic in sampling–base algorithm (e.g., RRT*)

GAN–based heuristic RRT*

Algorithm 1: Outline of GAN–based heuristic RRT*

Input : x_{init}, x_{goal}, Map – state space in the form of RGB image
Output: $G(V, E)$
$V = x_{init}$, $E = \varnothing$;
$\mathcal{S} \leftarrow$ ROIGenerator(x_{init}, x_{goal}, Map) ;
$\mathcal{X}_H \leftarrow$ Discretization($\mathcal{S}$);
$G(V, E) \leftarrow$ HeuristicSBP*(x_{init}, x_{goal}, Map, $\mathcal{H}$);
Return $G(V, E)$

Here $\mathcal{X}_H \subset \mathcal{X}_{free}$ is the state space where feasible paths exist with high probability

The focus of work lies in establishing an efficient generator to predict promising region $\mathcal{S}$ under the given conditions x_{init}, x_{goal}, Map

Heuristic RRT*

Algorithm 2: Heuristic RRT*

Input : x_{init}, x_{goal}, $\mathcal{H}$, Map
Output: $G(V, E)$
$V = x_{init}$, $E = \varnothing$;
for $i = 1 \cdots N$ **do**
    $x_{rand} \leftarrow$ Non-UniformSample($\mathcal{X}_H$);
end
$x_{nearest} \leftarrow$ Nearest(G, x_{rand});
$x_{new} \leftarrow$ Steer($x_{nearest}$, x_{rand});
if *ObstacleFree*($x_{nearest}$, x_{rand}) **then**
    Extend(G, x_{new});
    Rewire();
    if $x_{new} \in \mathcal{X}_{goal}$ **then**
        Return $G(V, E)$;
    end
end
Return Failure;

Dataset

- The maps (including obstacles), start and goal states are generated randomly
- To obtain the 'ground truth' regions the RRT was launched 50 times on each task.

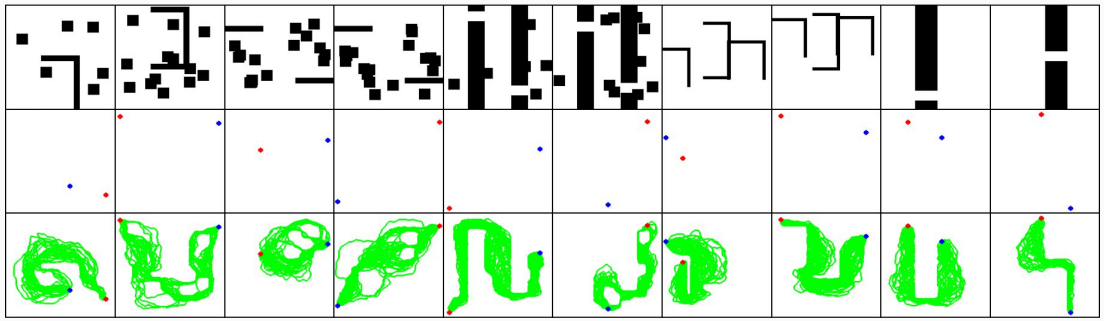
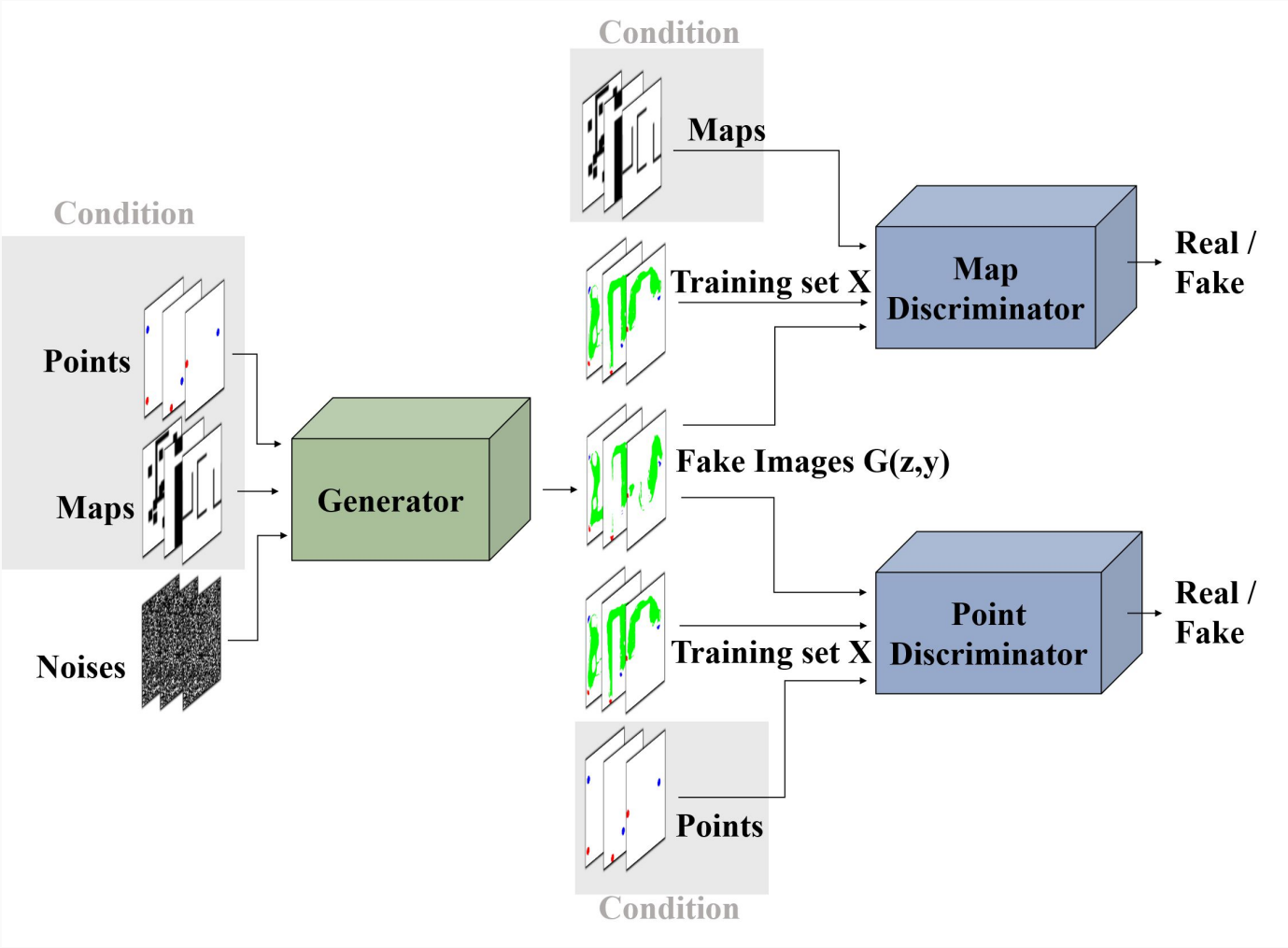


Figure: An illustration of the dataset

GAN


Condition
Maps
Condition
Points
Maps
Noises
Generator
Training set X
Map Discriminator
Real / Fake
Fake Images G(z,y)
Training set X
Point Discriminator
Real / Fake
Points
Condition

EVALUATION

Evaluation

As an image generation problem

- *The connectivity* (success rate, %) of the generated promising regions: if RRT algorithm is able to find feasible paths inside promising regions
- *Generalization ability* (success rate, %) of the model in completely different environments

As a path planning problem

- RRT* vs. RRT* with GAN–based heuristic
- Randomly choose one result from each type of the maps in the test set
- Metrics: path cost, number of nodes, planning time

RESPONSIBILITIES

Responsibilities

Timofey Zinenko
: Maps and feasible paths generation with RRT

Azamat Kanametov
: GANs, experiments

Alina Kolesnikova
: Embedding GAN–based heuristic into RRT*, experiments

DEADLINES

Deadlines

- Maps generation (due 18.04) – *partially done*
- Baselines from RRT* (due 25.04)
- GANs (due 25.04) – *partially done*
- Embedding GAN–based heuristic into RRT* (due 30.04)
- Evaluation, experiments, etc. (due 06.05)
- The project code is now available at *https://github.com/akanametov/PathGAN*

Thanks for attention!

Questions?