Benchmarking Combinatorially with Python

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December 3, 2019

Introduction

You have an awesome algorithm, **but**:

How can you ensure that it behaves better w.r.t. state-of-the-art?

- Theoretically? What if it's too complex?
- By comparing its *performances* on different *scenarios* with different *state-of-the-art algorithms*?

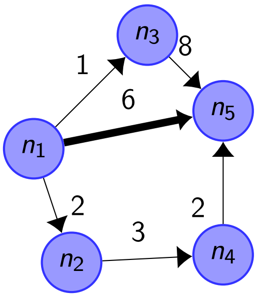
$\Downarrow$

Problem: the scenarios and the comparing algorithms may lead to too many combinations!
Goal: design a extensible framework that automatically performs all the combinations required for your performance testing;
Result a new Python software called `phd-tester` which performs automatic testing. Code available at
HTTPS://GITHUB.COM/KOLDAR/PHDTESTER

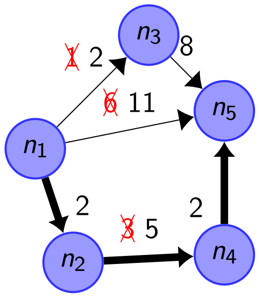
A Motivating Example (1)

Context: *dynamic* single agent pathfinding (given a weighted directed graph $\mathcal{G} = \langle N, E \rangle$, a *start* vertex s, a *goal* vertex t, what is the optimal path allowing an agent to reach t from s?); *dynamic* in the sense that, at the beginning of each pathfinding, some (arbitrary) edges temporary increase their cost (*perturbations*).

Example: going from $s = n_1$ to $t = n_5$



(a) original graph



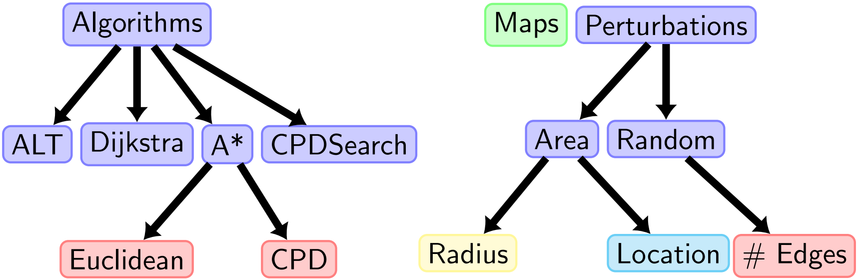
(b) Graph temporary altered

A Motivating Example (2)

We can solve it:

- 4 Algorithms: Dijkstra, `ALT`, A* + Euclidean Distance, A* + CPD, **CPD search** (our technique!);
- On which map? hrt201, dustwallowkeys, mazes512-1-4, rooms16-003, ...;
- How to generate perturbations? **R**andomly? If so how many **E**dges should we affect? Or by affecting a specific **A**rea along the optimal path? If so, how **W**ide the area is? Where should we affect the **P**ath?

A Motivating Example (3)



A Motivating Example (4)

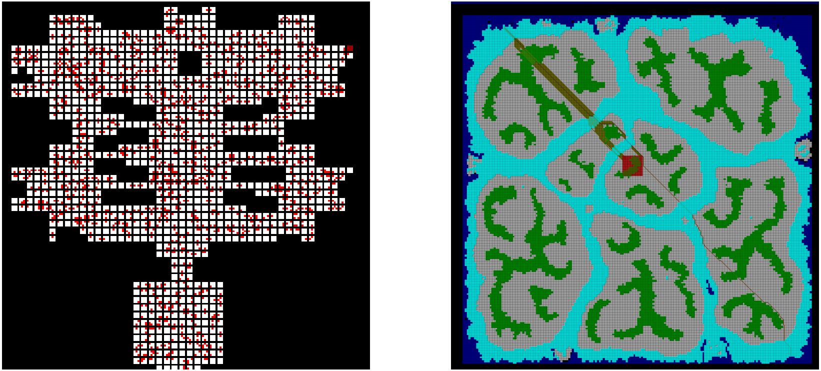


Figure: Example of perturbation policies. perturbations are shown in red. Left: random; Right: area

A Motivating Example (5)

$$|Algs| = 5, |Maps| = 4, |Perturbations| = 2$$

$$\Downarrow$$

$$Algs \times Maps \times Perturbations = 32$$

But **R** depends on parameter **E** while **A** depends on **W** and **P** parameters!

If we can choose the parameters:

- $E \in \{1\%, 5\%, 10\%\}$;
- $P \in \{20\%, 50\%, 100\%\}$;
- $W \in \{5, 10, 15\}$;

Maximum combinations: $32 \cdot |E \times P \times W| = 864$! If we add new parameters (which, in research, it happens quite often) maximum combinations significantly increases!

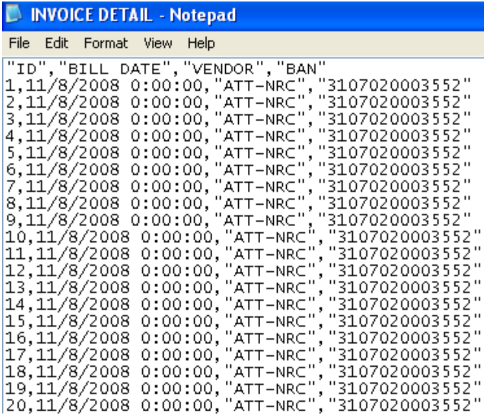
Talk Outline

The talk will be outlined as follows:

- Background: Software used;
- Proposed Technique: `KS001` and `phd-tester`;
- Experiments: testing with `CPD Search`;
- Conclusion and Future Works: integration with `CSPs` and generates automatic report pdf;

CSV file format

- Easy for storing data in “tabular” format;
- Human readable;
- can be read by tabular softwares (i.e., Excel, LibreOffice Calc);




```
"ID","BILL DATE","VENDOR","BAN"
1,11/8/2008 0:00:00,"ATT-NRC","310702003552"
2,11/8/2008 0:00:00,"ATT-NRC","310702003552"
3,11/8/2008 0:00:00,"ATT-NRC","310702003552"
4,11/8/2008 0:00:00,"ATT-NRC","310702003552"
5,11/8/2008 0:00:00,"ATT-NRC","310702003552"
6,11/8/2008 0:00:00,"ATT-NRC","310702003552"
7,11/8/2008 0:00:00,"ATT-NRC","310702003552"
8,11/8/2008 0:00:00,"ATT-NRC","310702003552"
9,11/8/2008 0:00:00,"ATT-NRC","310702003552"
10,11/8/2008 0:00:00,"ATT-NRC","310702003552"
11,11/8/2008 0:00:00,"ATT-NRC","310702003552"
12,11/8/2008 0:00:00,"ATT-NRC","310702003552"
13,11/8/2008 0:00:00,"ATT-NRC","310702003552"
14,11/8/2008 0:00:00,"ATT-NRC","310702003552"
15,11/8/2008 0:00:00,"ATT-NRC","310702003552"
16,11/8/2008 0:00:00,"ATT-NRC","310702003552"
17,11/8/2008 0:00:00,"ATT-NRC","310702003552"
18,11/8/2008 0:00:00,"ATT-NRC","310702003552"
19,11/8/2008 0:00:00,"ATT-NRC","310702003552"
20,11/8/2008 0:00:00,"ATT-NRC","310702003552"
```

Background and technologies used

- Language: Python 3[.6]: duck typing, scripting, `ABC` library, usually installed by default;
- ArangoDB: NoSQL graph-based database; basically we can store `JSON`; Compactly represent data;
- Pandas: allows operations on “dataframe” (≈ CSV);


```
{ ▼ 6 properties, 427 bytes
  "manifest_version": 2,
  "name": "JSON Lite",
  "version": "0.12",
  "description":
  large files, collapse items",
  "browser_action": { ▼ 1 property, 40 bytes
    "default_popup": "README.html"
  },
  "content_scripts": [ ▼ 1 item, 167 bytes
    { ▼ 4 properties, 157 bytes
      "all_frames": true,
      "matches": [ ▼ 1 item, 30 bytes
        "<all_urls>"
      ],
      "js": [ ▼ 1 item, 30 bytes
        "content.js"
      ],
      "run_at": "document_end"
    }
  ]
```

Design Patterns

- template: abstract class provides general behaviour with an concrete unmodifiable method *m* whilst derived classes implements single tasks used in *m* (e.g., `java.awt.Component`);
- Interface: allows usage of methods from a not-well specified object abstracting from its actual implementation;
- API: a method or a service a library or a third-party system provides to the developer in order to perform a task;

Main Ideas

Each **test** $t \in \mathcal{T}$ involves a **stuff** $s \in \mathcal{S}$ to test (e.g., algorithm) and an **environment** $e \in \mathcal{E}$ where the test occurs (e.g., path finding map) Each **stuff**(**environment**) is a tuple of $n(m)$ values of parameters $p_i \in \mathcal{P}$ (e.g., number of edge to perturbate, heuristic to use), where each parameter value v_i has a specific domain $\mathcal{D}_i \cup \{nil\}$ (NIL). All Elements in $\mathcal{S}(\mathcal{E})$ share the same tuple structure.

The final application is composed by 2 parts:

1. a **library** which the user call and provide a *template design pattern* with easy APIs (provided by `phd-tester`);
2. a **user code** which implements the *template design pattern*, providing mandatory information about the test as well as actually call the program to test (pro: test can be coded with any language!).

Template to follow

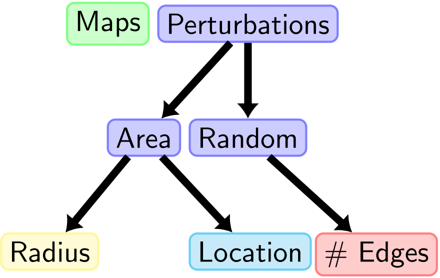
High-level steps in the *template* provided by the framework:

1. the user specifies all the parameter values he wants (e.g., perturbation generation policy $\in \{\text{random}, \text{area}\}$);
2. the application generates all the required tests $\mathcal{T}^* \subseteq \mathcal{T}$;
3. the application executes all the tests $t \in \mathcal{T}^*$;
4. the application produces generate n CSVs representing test outcome (note $n \geq |\mathcal{T}^*|$);

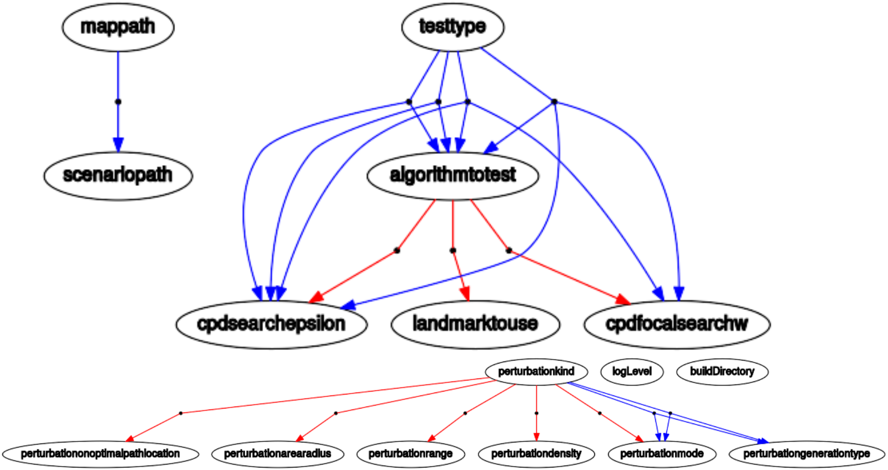
Option Graph

The user specifies all the parameter values he wants (e.g., perturbation generation policy $\in \{\text{random}, \text{area}\}$);

By command line. In order to build the CLI interface, developer needs in *user code* to declare the **option graph**: $\forall p_i \in \mathcal{P}$ say its domain $\mathcal{D}_i$, and what constraints it implies (e.g., if parameter `perturbationPolicy` is set to `random`, then the CLI needs to specify parameter value `edge number`).



Example of Option graph



CLI generated

```
usage: main.py [-h] [--algorithmtotest_values ALGORITHMTOTEST_VALUES]
               [--cpdsearchepsilon_values CPDSEARCHEPSILON_VALUES]
               [--cpdfocalsearchw_values CPDFOCALSEARCHW_VALUES]
               [--landmarktouse_values LANDMARKTOUSE_VALUES]
               [--testtype_values TESTTYPE_VALUES]
               [--mappath_values MAPPATH_VALUES]
               [--scenariopath_values SCENARIOPATH_VALUES]
               [--perturbationkind_values PERTURBATIONKIND_VALUES]
               [--perturbationgenerationtype_values PERTURBATIONGENERATIONTYPE_VALUES]
               [--perturbationmode_values PERTURBATIONMODE_VALUES]
               [--perturbationonoptimalpathlocation_values PERTURBATIONONOPTIMALPATHLOCATION_VALUES]
               [--perturbationarearadius_values PERTURBATIONAREARADIUS_VALUES]
               [--perturbationrange_values PERTURBATIONRANGE_VALUES]
               [--perturbationdensity_values PERTURBATIONDENSITY_VALUES]
               [--logLevel LOGLEVEL] [--buildDirectory BUILDDIRECTORY]

optional arguments:
  -h, --help            show this help message and exit
  --algorithmtotest_values ALGORITHMTOTEST_VALUES
                        . Accepted values are CPD-SEARCH CPD-FOCAL-SEARCH ALT
  --cpdsearchepsilon_values CPDSEARCHEPSILON_VALUES
  --cpdfocalsearchw_values CPDFOCALSEARCHW_VALUES
                        Focal Search W bound
  --landmarktouse_values LANDMARKTOUSE_VALUES
  --testtype_values TESTTYPE_VALUES
                        . Accepted values are OPTIMAL BOUNDED
```

Generation of $\mathcal{T}^*$

the application generates all the required tests $\mathcal{T}^* \subseteq \mathcal{T}$.

$\mathcal{T}^*$ represents all the tests which we are required to execute. Some cartesian products in $\mathcal{S} \times \mathcal{E}$ are simply invalid (e.g., `number of edges to perturbate` set to '*nil*' when the `perturbation policy` is *random*).

`phd-tester` exploits the option graph not only to generate the CLI, but also to detect parameters dependendencies.

Example: Given a $t \in \mathcal{T}$ if `perturbation policy` is *random*, require that `number of edges`$\neq$ '*nil*': if it is true, add t in $\mathcal{T}^*$).

Execute tests

The application produces generate n CSVs representing test outcome (note $n \geq |\mathcal{T}^*|$);

In this step the **user code** has all the freedom it desires. Usually the developer is expected to call an external program (e.g., coded in `C` or in `C++`) that actually performs the test. As a side effect, one or more CSVs are expected to be produced somewhere (i.e., file system, ArangoDB, mySQL $\Rightarrow$ **Data source**).

- **Problem:** how to identify which CSVs have been generated by which test $t \in \mathcal{T}^*$?
- **Solution:** by creating a new naming convention of file: `KS001`;

KS001 standard

Idea

The filename is composed by `basename` and `extension`. `basename` is a **ordered** sequence of substring separated by |, and it is optionally prefixed by a `label`. Each substring is a unordered sequence of keyvalues string, separated by _. Each keyvalue follows the pattern `key=value`.

```
filename := identifier? '|' dictionaries '|' extension?
dictionaries := dictionary ( '|' dictionaries )*
dictionary := name ':' keyvalues* | keyvalues
keyvalues := keyvalue  ( '_' keyvalues )*
keyvalue := key '=' value

name := string
identifier := [^|]+
extension := string
key := string
value := string

string := ([^=_|:]|'='{2}|'_'{2}|'|'{2}|':'{2})+
```

Example of KS001

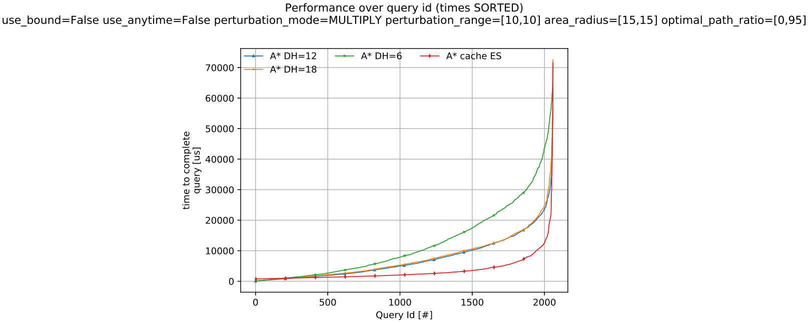
```
|mp=16room__003.map_pd=0.1_pgt=PER-SCENARIO_pk=RANDOM
_pm=MULTIPLY_pr=[3,3]_sp=16room__003.map.scen
|generated:type=id-over-time|.csv
```

- doubling special characters if shown in key(value);
- aliasing of key(values) to avoid long names (you may reach path size limit);
- labelling of dictionary increase readability;
- phd-tester offers a set of function to query and manage KS001 compliant strings;

Generation of interesting data (1)

The application produces generate n CSVs representing test outcome (note $n \geq |\mathcal{T}^*|$);

We use all the CSVs produced in the previous phase and stored in a **data source** to generate *new* CSVs representing the benchmarks (and optionally, the related graphs as well).



Generation of interesting data (2)

`phd-tester` dynamically generate these csv(image).

- each csv(image) is often produced by analyzing one or more outputs of tests in $\mathcal{T}^*$;
- `phd-tester` provides **masks**, which acts as filter allowing the software to fetch a subset of $\mathcal{T}^*$ to consider to produce a new csv(image) (e.g., produce time used by all algorithm depending on the number of edge perturbated in the map);
- The number of CSVs to analyze may be huge (maybe over 30000, each with 100 an more rows!). `phd-tester` used `pandas` along with `dask` to concurrently computes the operations $\Rightarrow$ fast;
- `CurveChanger`: allows to further alters the functions generated by adding/removing/sorting values;

Conclusions and Future Works

In conclusion:

- We have developed `phd-tester`, an extensible framework to combinatorially testing algorithms, parametrized both in regard of what we're testing and of the environment of the test;
- proposed a naming convention of files which is both human readable and software parsable (`KS001`);
- developed a mechanism to concurrently computed generated data and plot it;
- **Future works:** integrate MySQL as data source; generate automatic pdf reports of the tests done; Use a CSP to build the option graph. See `https://github.com/Koldar/phdTester/issues` for further works to be done.