R-Trees for tracking reconstruction

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Previous works

- A reconstruction algorithm that expands the tracks by checking the closest hits to them.
- Problem: hits were stored in a linear data structure.
  - All the hits belongs to a 3D coordinate system. How to organize them?
  - We had to traverse all the structure to find the K nearest hits.

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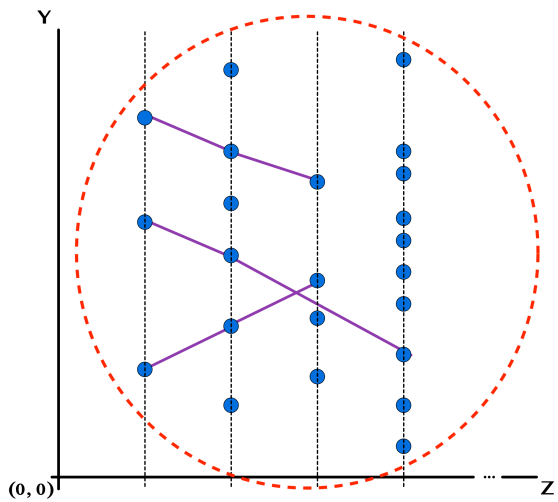


Figure 1: Using the linear data structure

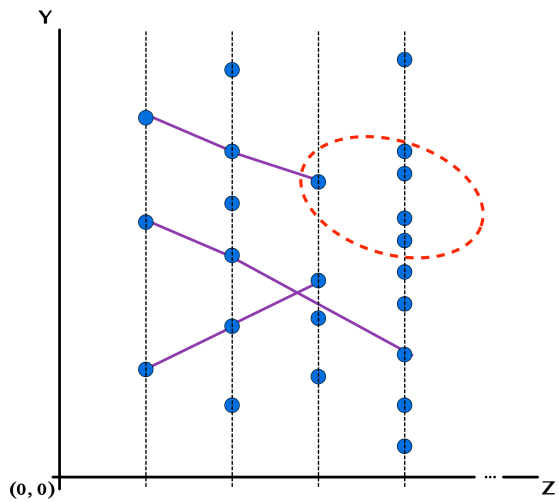


Figure 2: We want to check the closest hits for a line track

First solution

- Use an existing API for spatial data indexing that implements a **R-Tree**.
- The API is implemented in C++ but uses Cython to be usable with Python with the power of the C++ language.

R-Tree

- Based on B-Trees.
- Inner nodes contains M entries with M regions.
- Leaf nodes contains M *hits*.
- KNN searches.

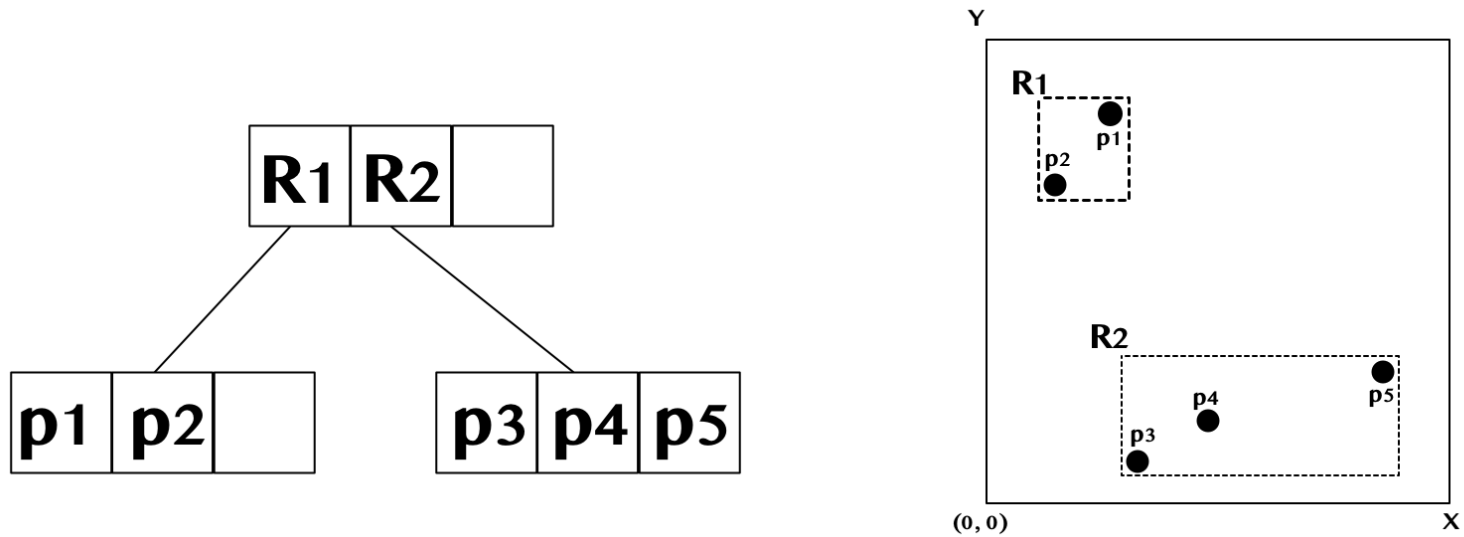


Figure 3: Example of a R-Tree with M = 3

R-Tree: Insertion

- Regions increases to cover all the hits.
- The region implying the minimum increase is chosen to cover the new hit.

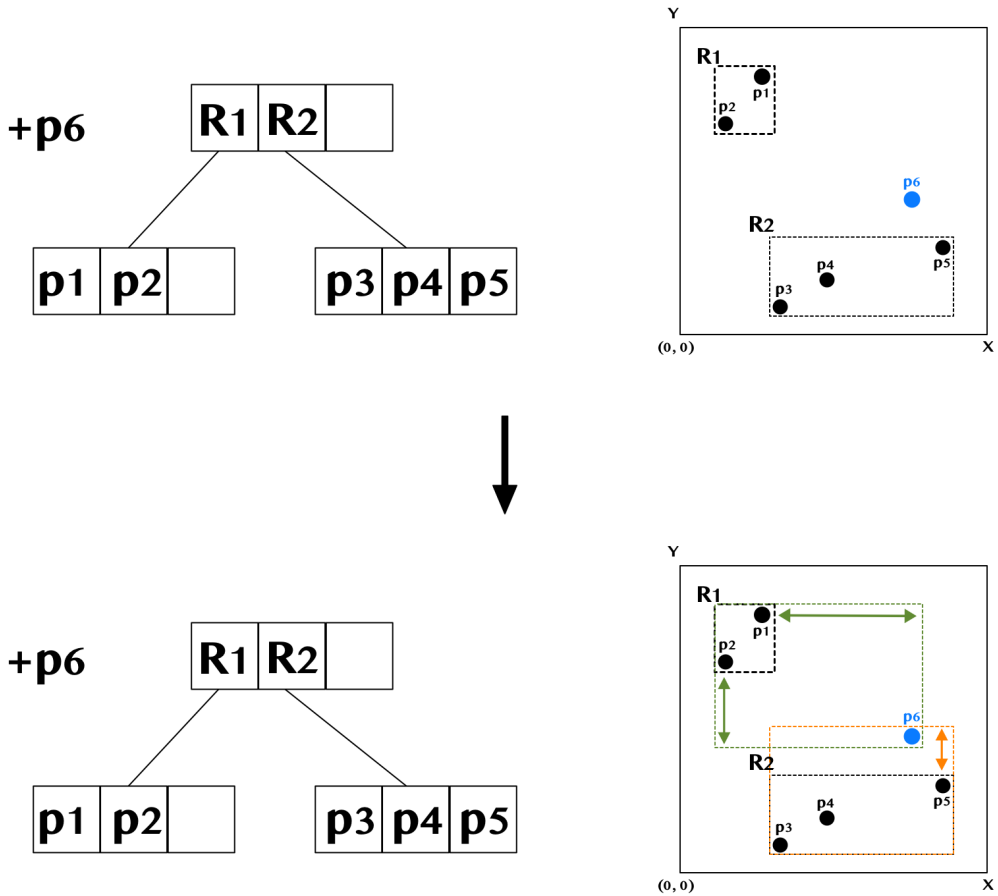


Figure 4: Insertion example

R-Tree: *Overflow*

- The node where the hit should be stored is full.
- It is needed to perform a node **split** (figure 5).

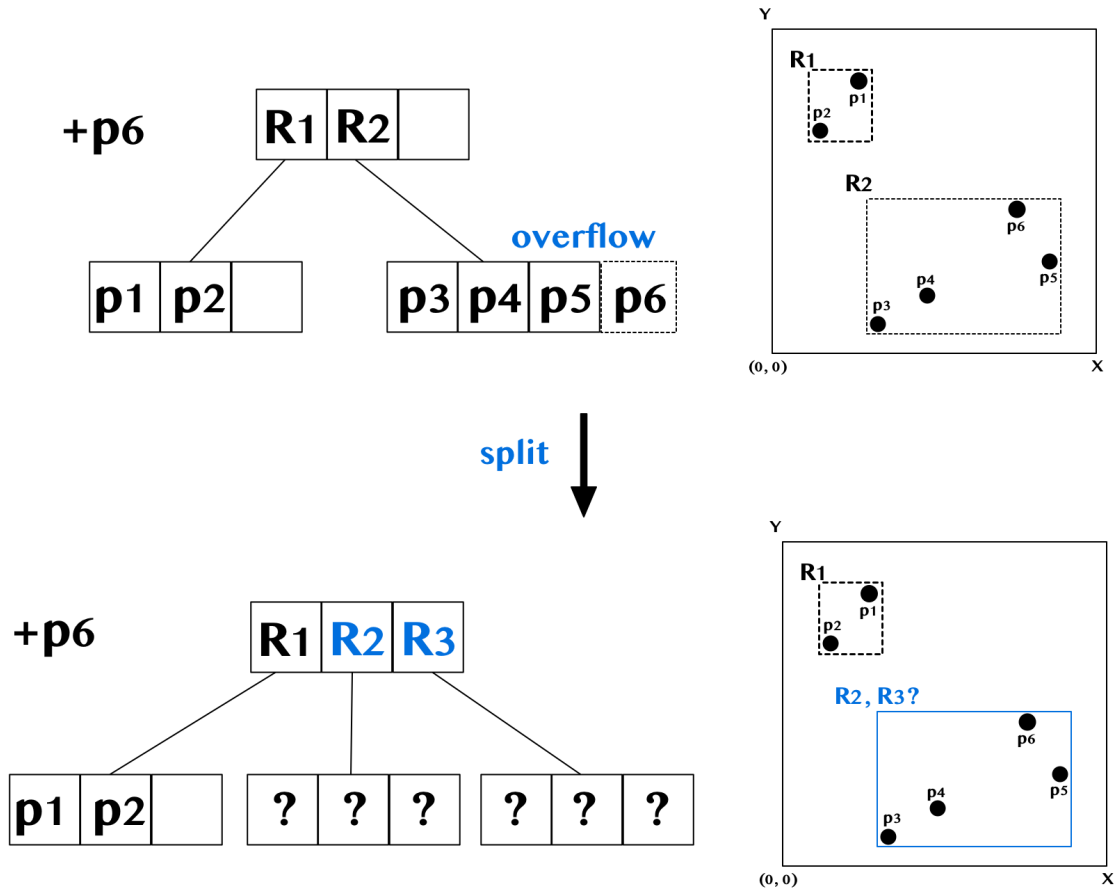


Figure 5: Hits of the node split must be distributed over the new two resulting nodes

R-Tree: *Split*

- Hits distribution must be as optimal as possible (figure 6).
- **Bad distribution** (figure 7) will imply **slow searches**.

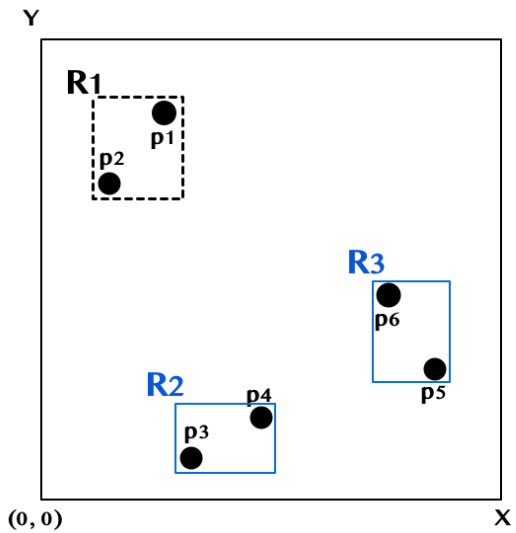


Figure 6: Perfect distribution

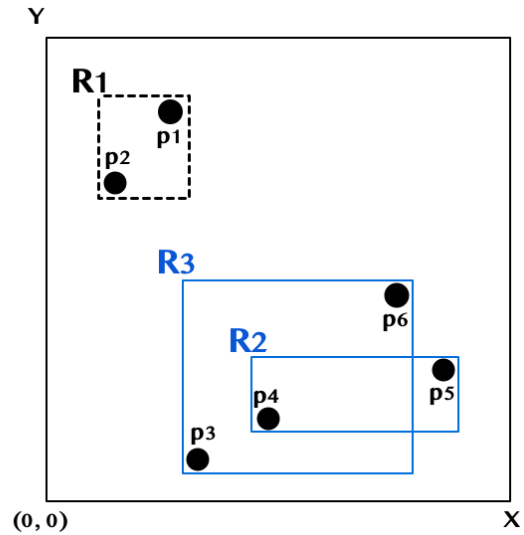


Figure 7: Bad distribution

R-Tree: Split algorithms

- There are many split algorithms:
  - Exponential
  - Quadratic
  - Linear
- The R-Tree API uses quadratic split.

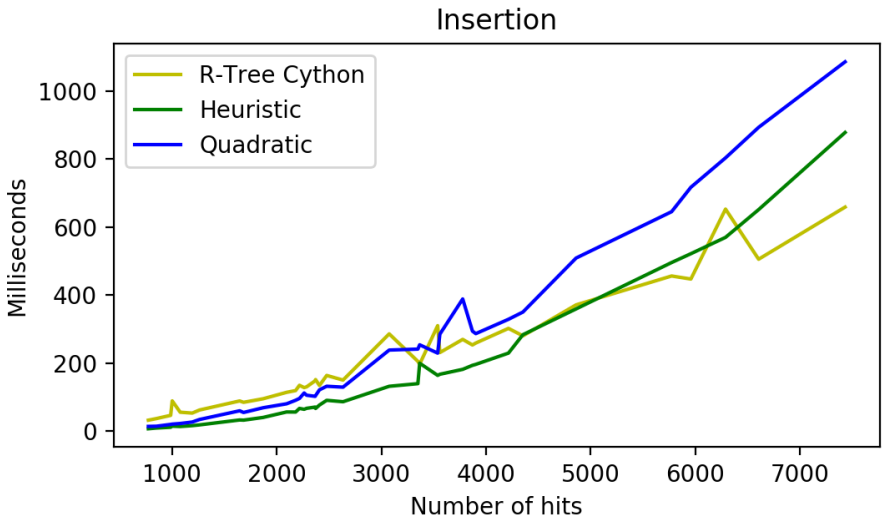
Second solution

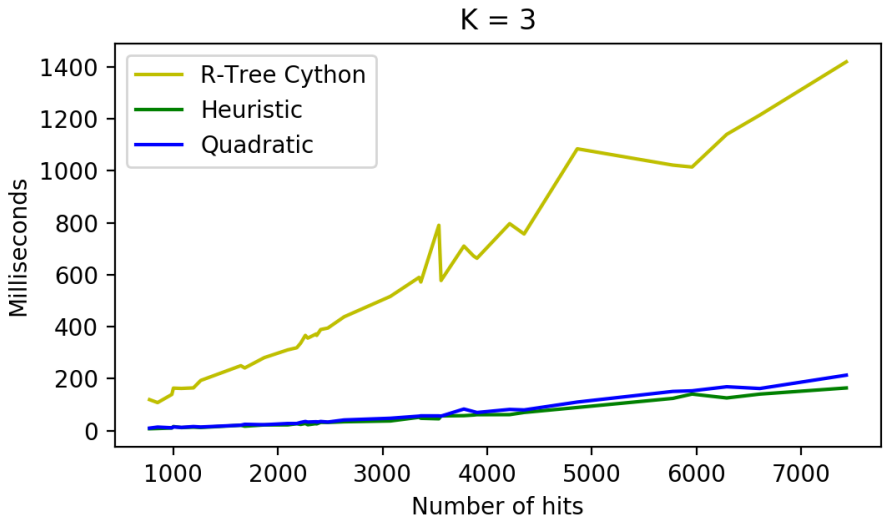
- R-Tree API presents some **problems**
  - We cannot add/change the split algorithm being used.
  - Generic structure.
  - Last update was in 2011.

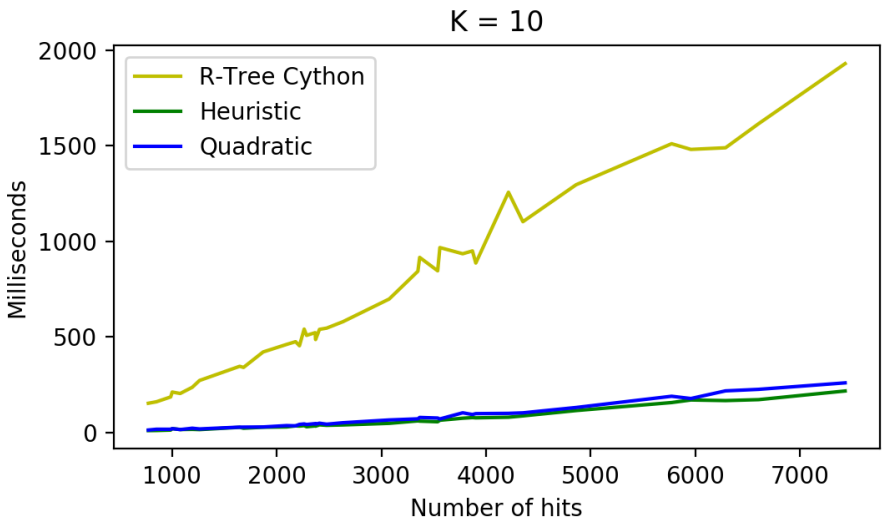
Second solution

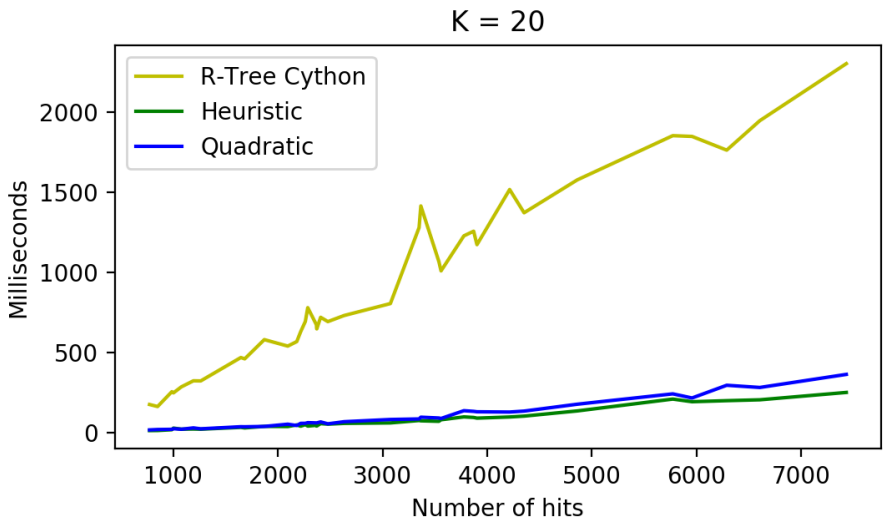
- R-Tree API presents some **problems**
  - We cannot add/change the split algorithm being used.
  - Generic structure.
  - Last update was in 2011.
- **Next step**: create a R-Tree project in C with a flexible implementation.
  - Add custom split algorithms.
  - Change other properties.
  - We tried it with VELO datasets using the quadratic split and a custom heuristic algorithm.

Results


Insertion
R-Tree Cython
Heuristic
Quadratic
Milliseconds
Number of hits
0
200
400
600
800
1000
1000
2000
3000
4000
5000
6000
7000


K = 3
R-Tree Cython
Heuristic
Quadratic
Milliseconds
Number of hits
0
200
400
600
800
1000
1200
1400
1000
2000
3000
4000
5000
6000
7000


K = 10
R-Tree Cython
Heuristic
Quadratic
Milliseconds
Number of hits
0
500
1000
1500
2000
1000
2000
3000
4000
5000
6000
7000


K = 20
R-Tree Cython
Heuristic
Quadratic
Milliseconds
Number of hits
0
500
1000
1500
2000
1000
2000
3000
4000
5000
6000
7000

Conclusions

- Insertion is not always faster than the Python API.
- Significant decrease of KNN execution time compared to the Python API.
- Easy adaptable project: add new split algorithms with no need to understand all the implementation.

Questions?