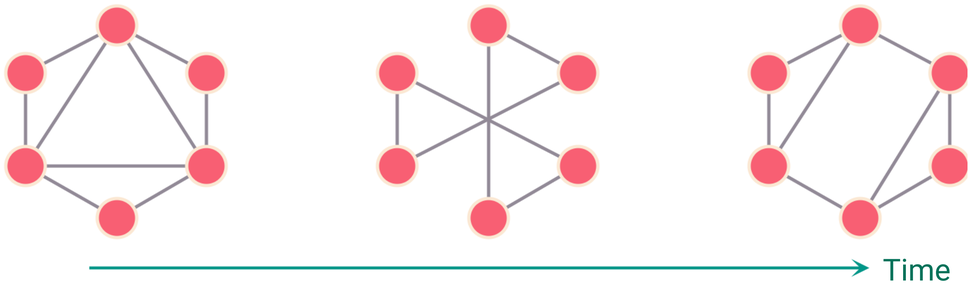
# Path Planning for Dynamic Graphs using A* on GPU

## Abstract


- A* is one of the widely used path planning algorithms applied in a diverse set of problems in robotics and video games.
- Zhou and Zeng [1] proposed a parallel variant of A* for GPU, which keeps multiple priority queues to find the optimal path in a static graph ( static A*).
- Here we present A* for dynamic graphs (dynamic A*) on GP-GPUs which achieves 2x-7x speedup than static A* on the SNAP dataset [2]


## Dynamic Graphs




## Dynamic A*: Insertion of edges

- Newly added edges can alter the optimal path.
- To find the new optimal path instead of executing A* from scratch, we propagate the change to the affected nodes of the graph.

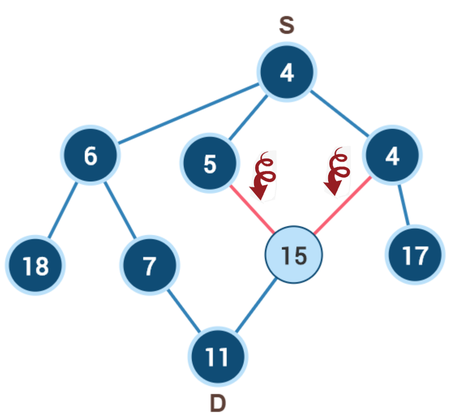



Fig 1: Two threads processing newly added edge ( shown in red )

### Pseudocode!

1. For edges(u, v) inserted, add node v to update_list, if $f(v)_{new} < f(v)_{old}$.
2. While update_list not empty:
   a. Extract node n from update_list.
   b. For each child of n:
      i. **lock(child)**
      ii. if $f(child)_{new} < f(child)_{old}$, add child to update_list.
      iii. **unlock(child)**

f(v) : cost of node v = g(v) + h(v)

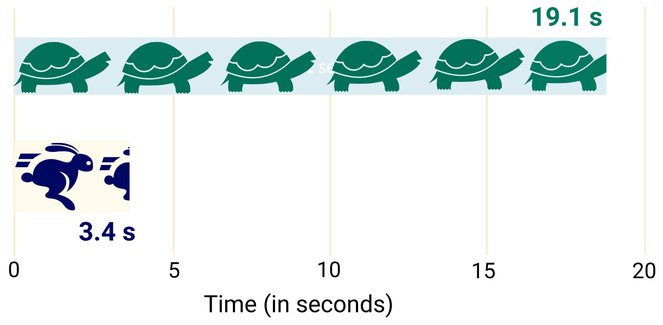
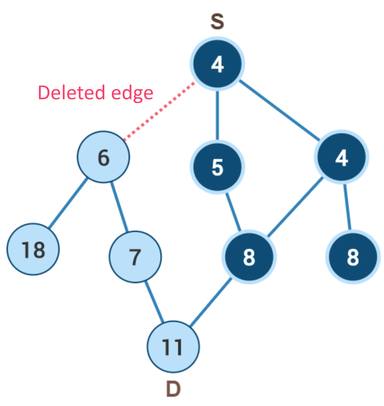




Fig 2: Execution time of static A* and dynamic A* on graph Wiki-Talk

## Dynamic A*: Deletion of edges

- Deleting only that edge which belongs to the optimal path can create a new optimal path.
- For all such affected nodes recompute the cost and select the neighbour with the least cost.
- Propagate the updated cost to all the affected nodes.




Nodes affected by deletion of the edge

### Pseudocode!

1. For each deleted edge u → v:
   **a.** Compute f(v) from the neighbours of v.
   **b.** Add v to update_list.
2. While update_list is not empty:
   **a.** Extract node **n** from update_list.
   **b.** For each child of **n** such that optimal_parent(child) = **n**:
      **i.** If $f(child) > f(child)_{new}$ then compute cost of child from each of its neighbour and add it to update_list.

**optimal_parent(v):** neighbour of node v with least f(v)

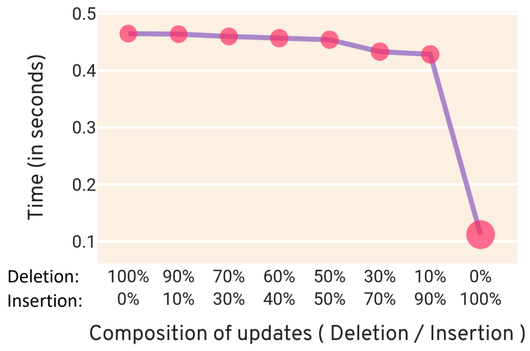
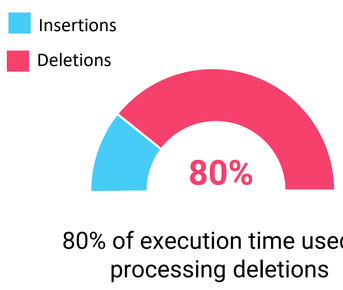



Fig 3: Execution time vs composition of updates




80% of execution time used in processing deletions

## Dynamic A*: Fully Dynamic

- The update contains both insertion and deletion of edges.
- Propagate insertions and deletions of edges separately.
- Performs better than re-executing static A* algorithm after each update.


5x Speedup by using dynamic A*

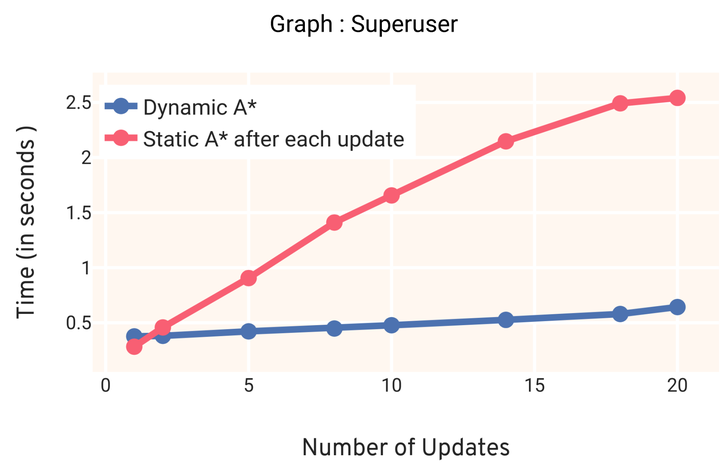



Fig 4 : Execution time vs number of updates In the graph

## Results

The below table shows execution time (in seconds) and speedup of dynamic A* compared to re-executing static A* every time.

| No. | Graph | Edges | Queries | Dynamic A* | Static A* | Speedup |
|---|---|---|---|---|---|---|
| 1 | Live Journal | 34,681,189 | 10 | 6.01 | 33.93 | **5x** |
| 2 | Wiki Talk | 7,833,140 | 10 | 12.24 | 24.84 | **2x** |
| 3 | Ask Ubuntu | 964,437 | 10 | 0.25 | 1.31 | **5x** |
| 4 | YouTube | 2,987,624 | 10 | 0.81 | 5.78 | **7x** |
| 5 | Math Overflow | 506,550 | 10 | 0.09 | 0.67 | **7x** |
| 6 | Live Journal | 34,681,189 | 100 | 11.41 | 424.06 | **37x** |

## Applications

1. We have applied dynamic A* on energy efficient routing protocol (EERP) and achieved 35x speedup from static A*.


35x Speedup by using dynamic A*

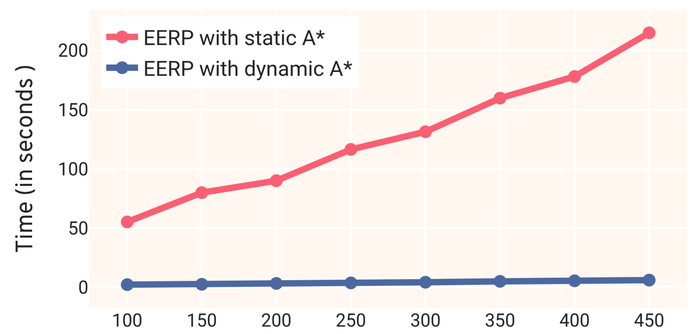
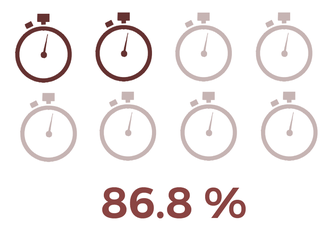
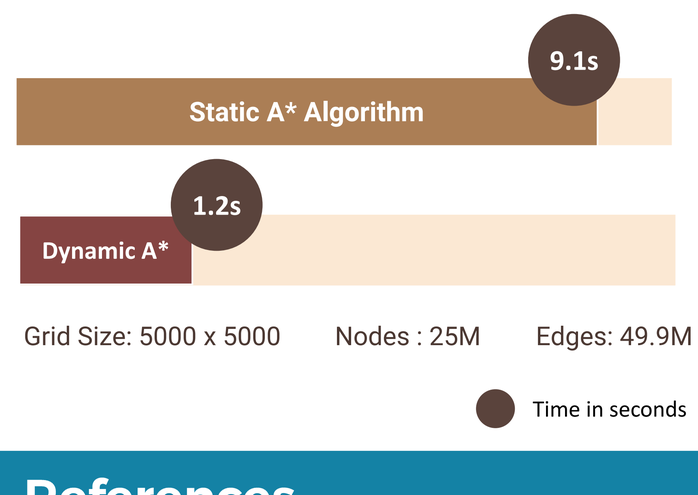



Fig 5: Comparison b/w static A* and dynamic A* on EERP algorithm

2. On applying dynamic A* for pathfinding in the maze, we achieved 8x speedup.




reduction in execution time by using Dynamic A* algorithm.




## References


1. Yichao Zhou and Jianyang Zeng. “Massively Parallel A* Search on GPU”. In: Twenty-Ninth AAAI Conference on Artificial Intelligence (2015).
2. Jure Leskovec and Andrej Krevl. SNAP Datasets: Stanford Large Network Dataset Collection. http://snap.stanford.edu/data. June 2014.


! Pseudocode described above is to give a basic idea of the algorithm. It does not cover all the cases, for more information please refer to GitHub.