Search for Optimal Solutions: the Heart of Heuristic Search is Still Beating

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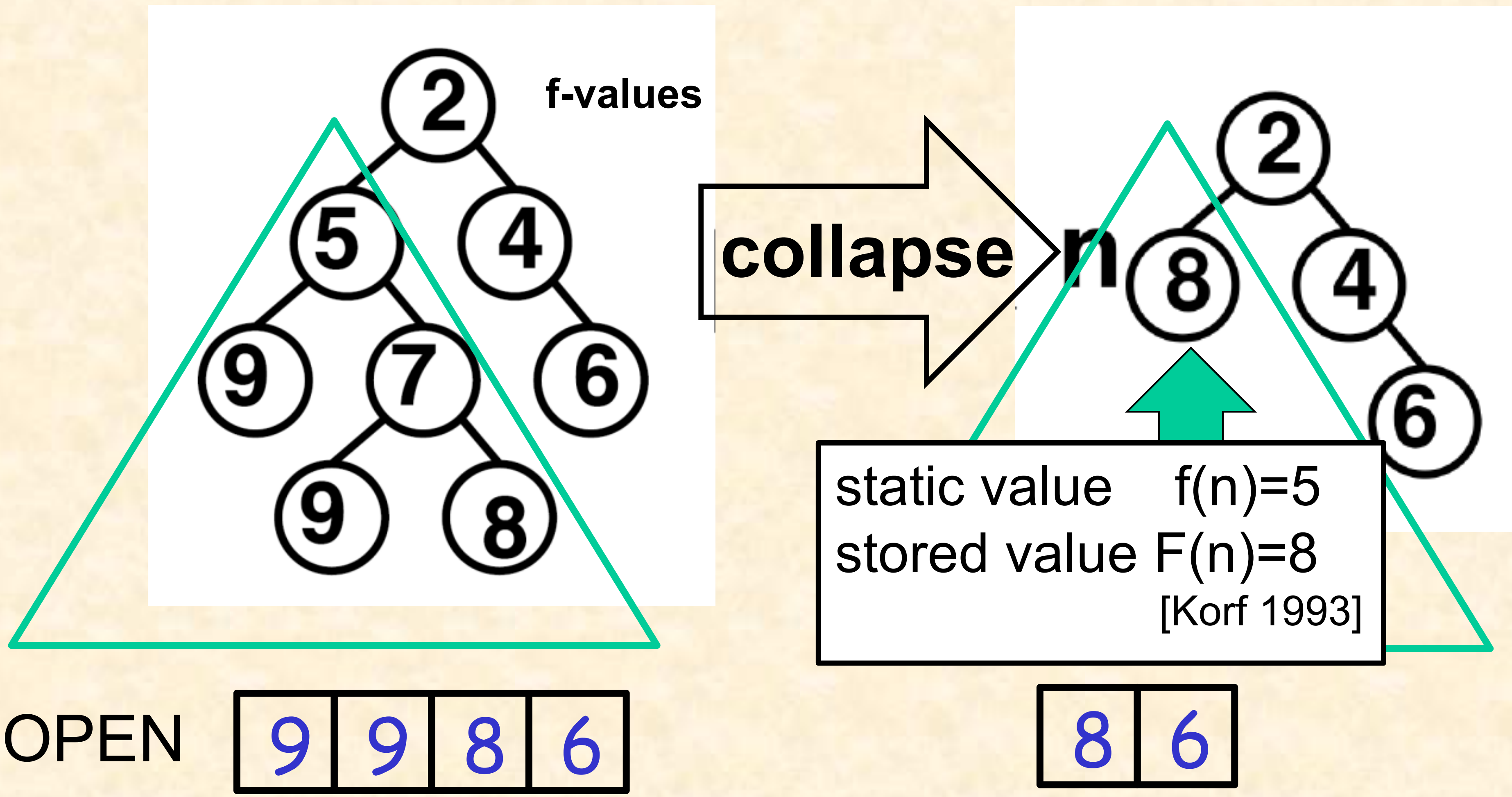
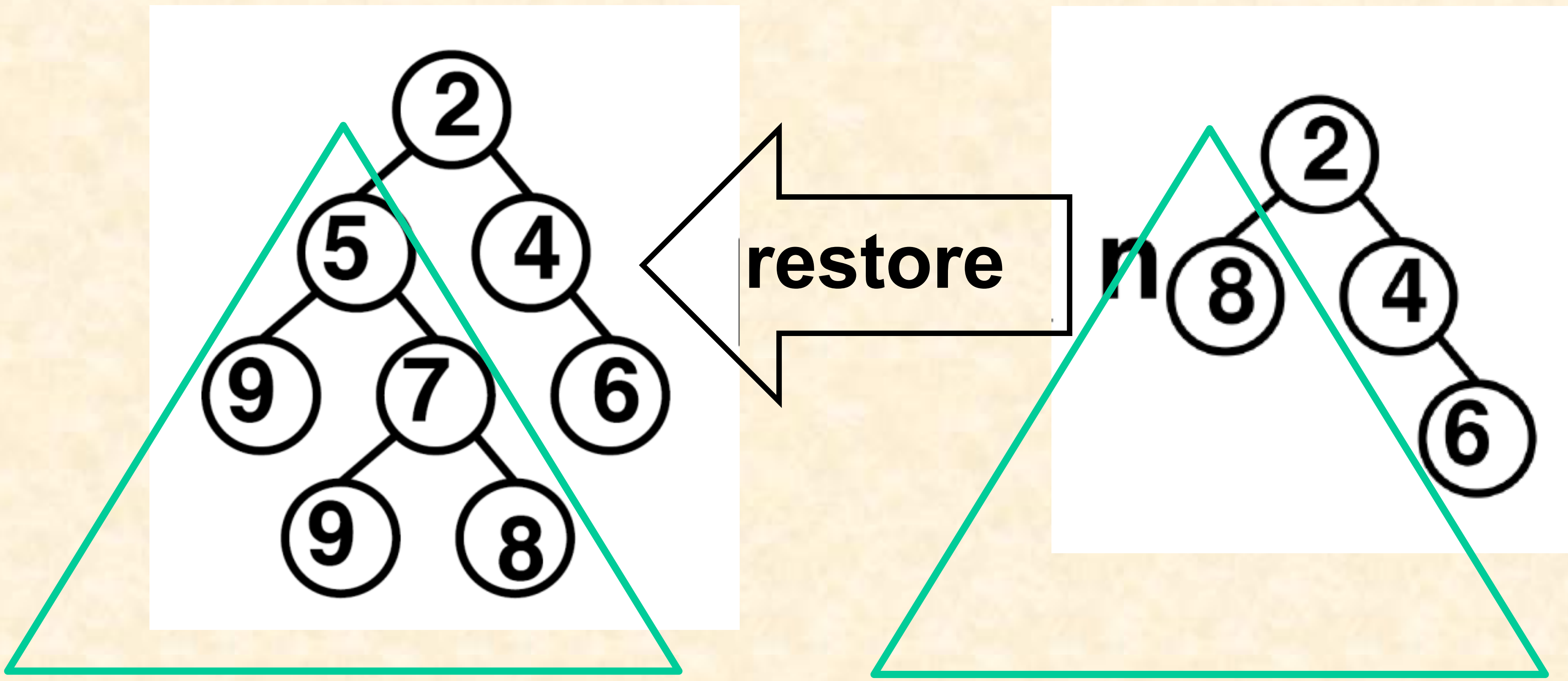
2. Collapse and Restore macros

[#1, SoCS-2015]

2.1 Collapse macro for best-first search



Restore macro



OPEN				
	9	9	8	6

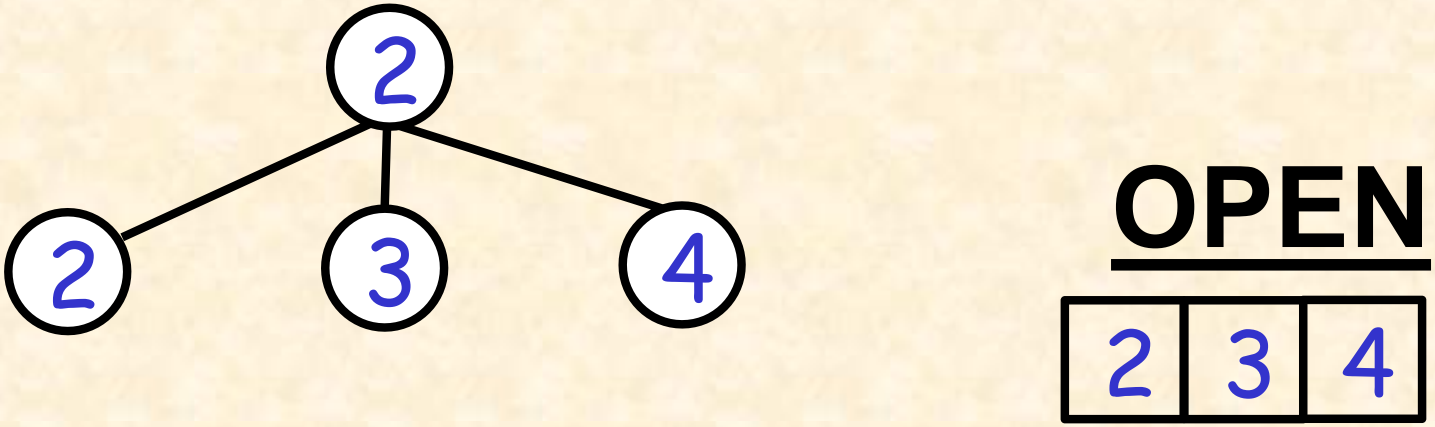
8	6

- Collapse is a **lossy** compression
  1) How do we know a node was collapsed?
  2) How do we restore?

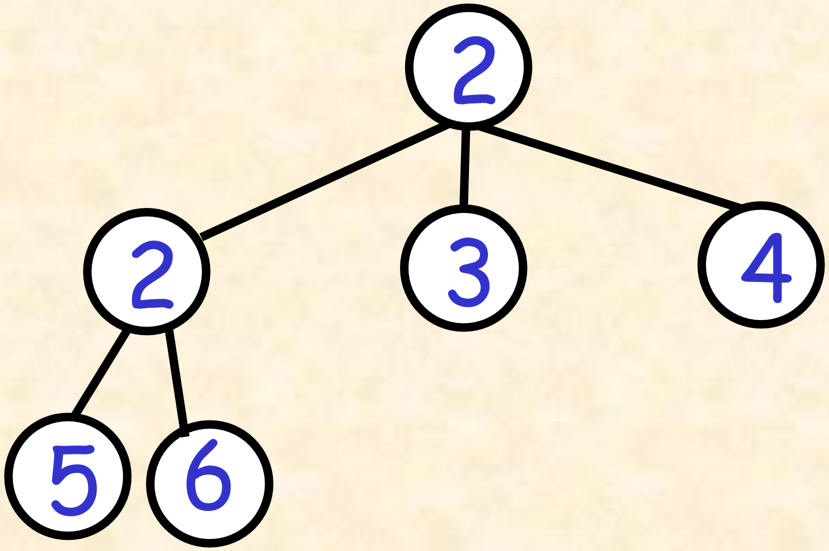
<u>Restore is algorithm dependent</u>

If F(n) > f(n) and the f-value is monotonically increasing just perform a bounded DFS by F(N). [Korf 1993]

2.2 SMA* [#2:Russell 1992]



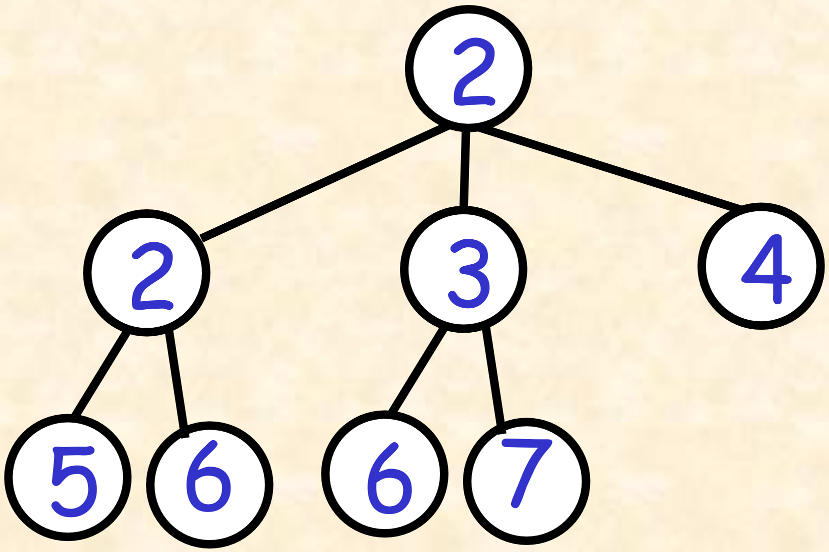
SMA* [Russell 1992]



OPEN

3	4	5	6

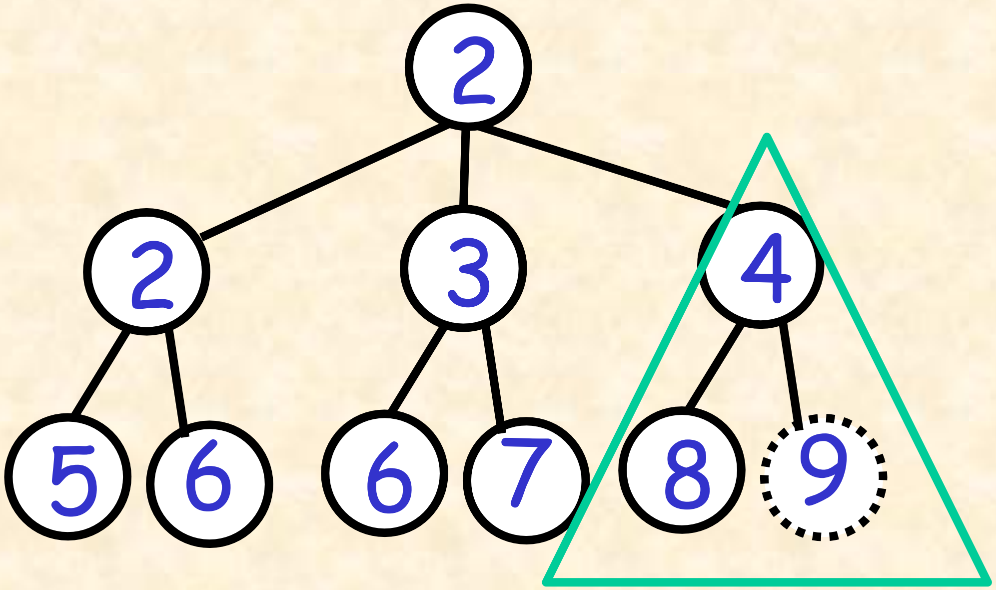
SMA* [Russell 1992]



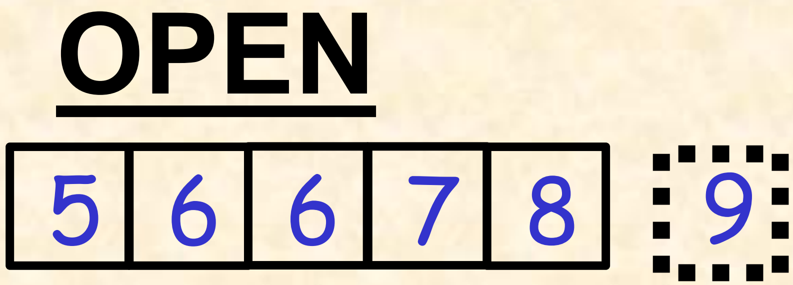
OPEN

4	5	6	6	7

SMA* [Russell 1992]



collapse



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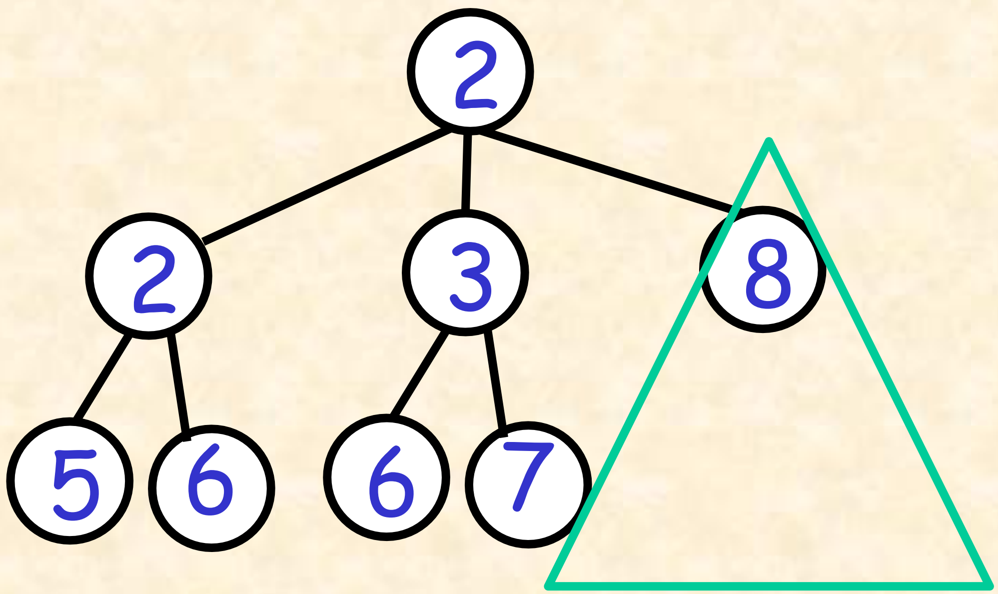
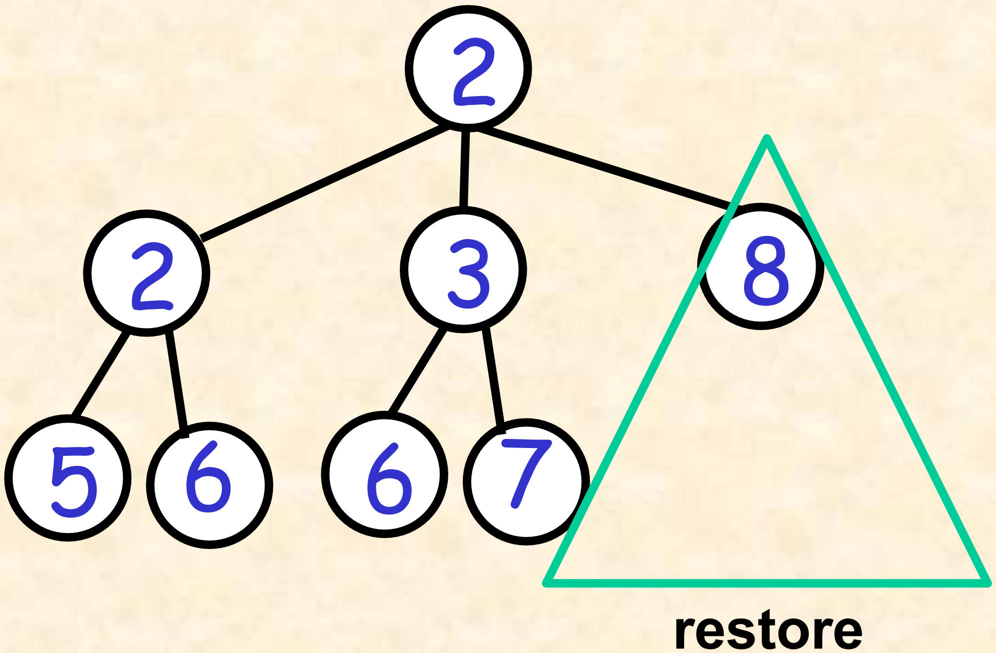


OPEN

5	6	6	7	8

SMA* [Russell 1992]



OPEN

5	6	6	7	8

SMA* uses a variant of pathmax for its restore macro

2.3. ILBFS [#1 SoCS-2015]

Iterative linear best-first search

Iterative variant of RBFS [Korf, AIJ 1993]

Algorithm 1: High-level ILBFS

```
Input: Root R
Insert R into OPEN and TREE
oldbest=NULL
while OPEN not empty do
    best=extract_min(OPEN)
    if goal(best) then
        exit
```

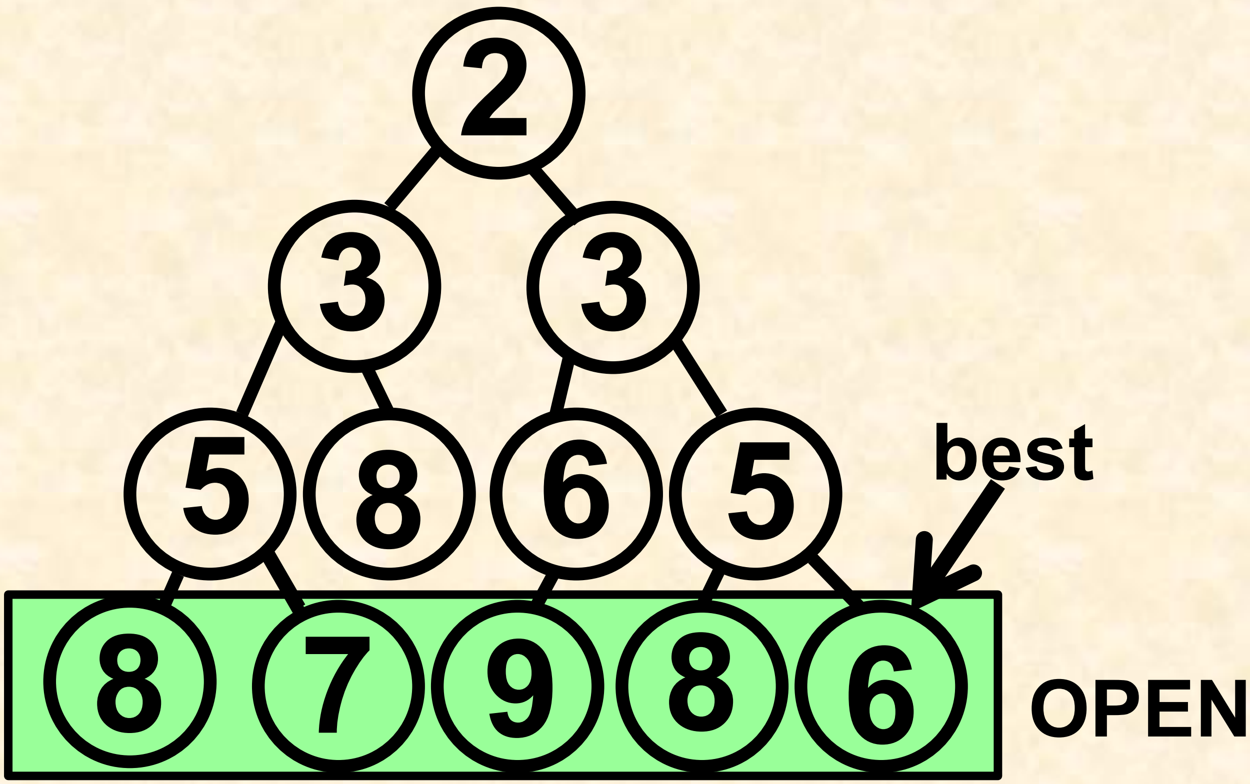
Collapse

Restore

```
    foreach child C of best do
        Insert C to OPEN and TREE
    oldbest ← best
```

- Uses the regular BFS expansion cycle
- Heavily uses the collapse and restore macros

ILBFS

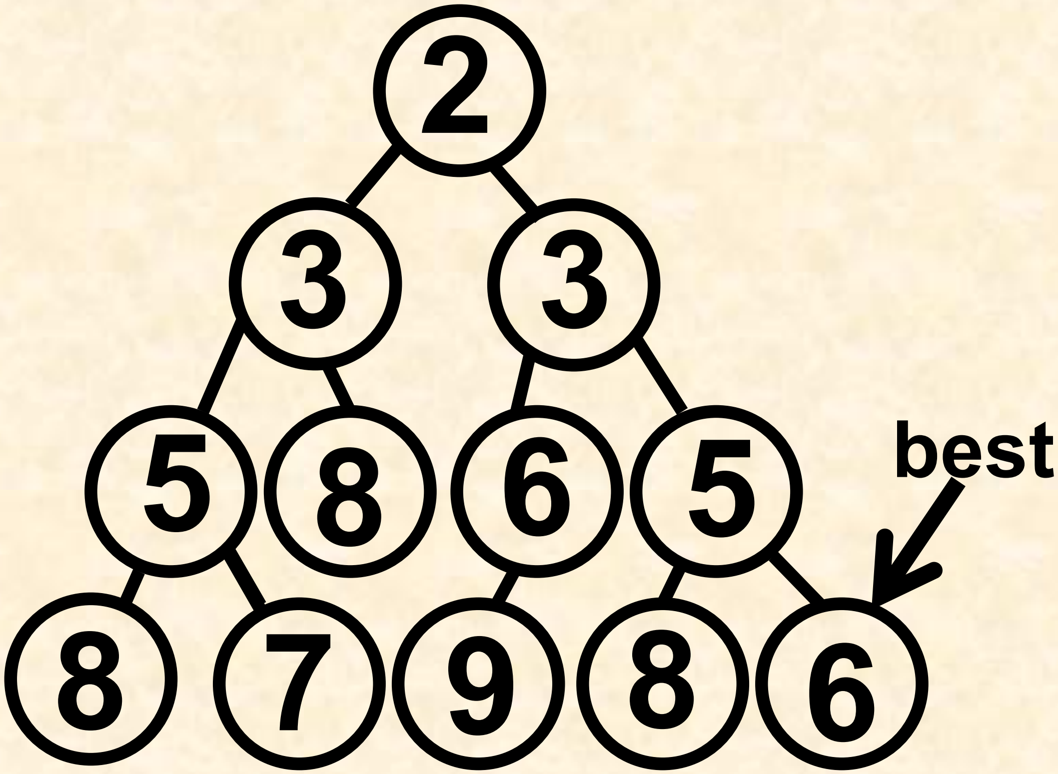


Classic BFS

Principal branch invariant

Store only the branch of the best node and its siblings

ILBFS



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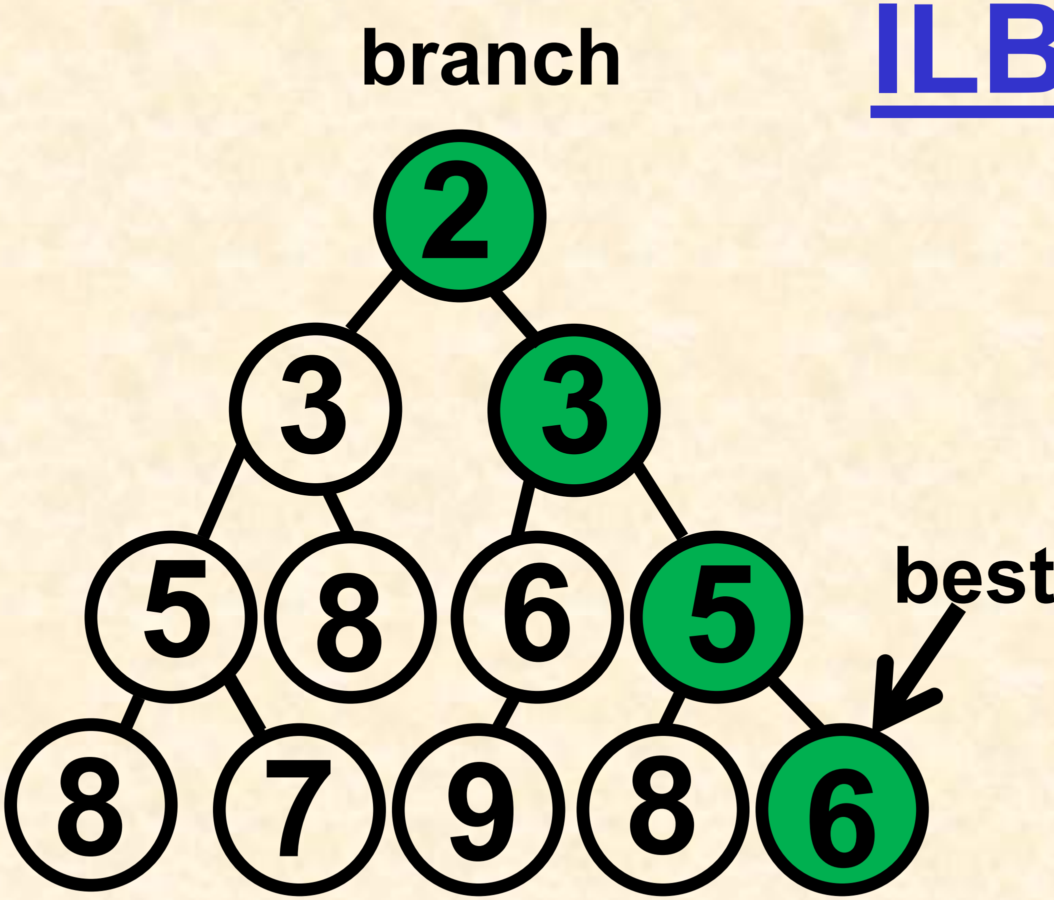

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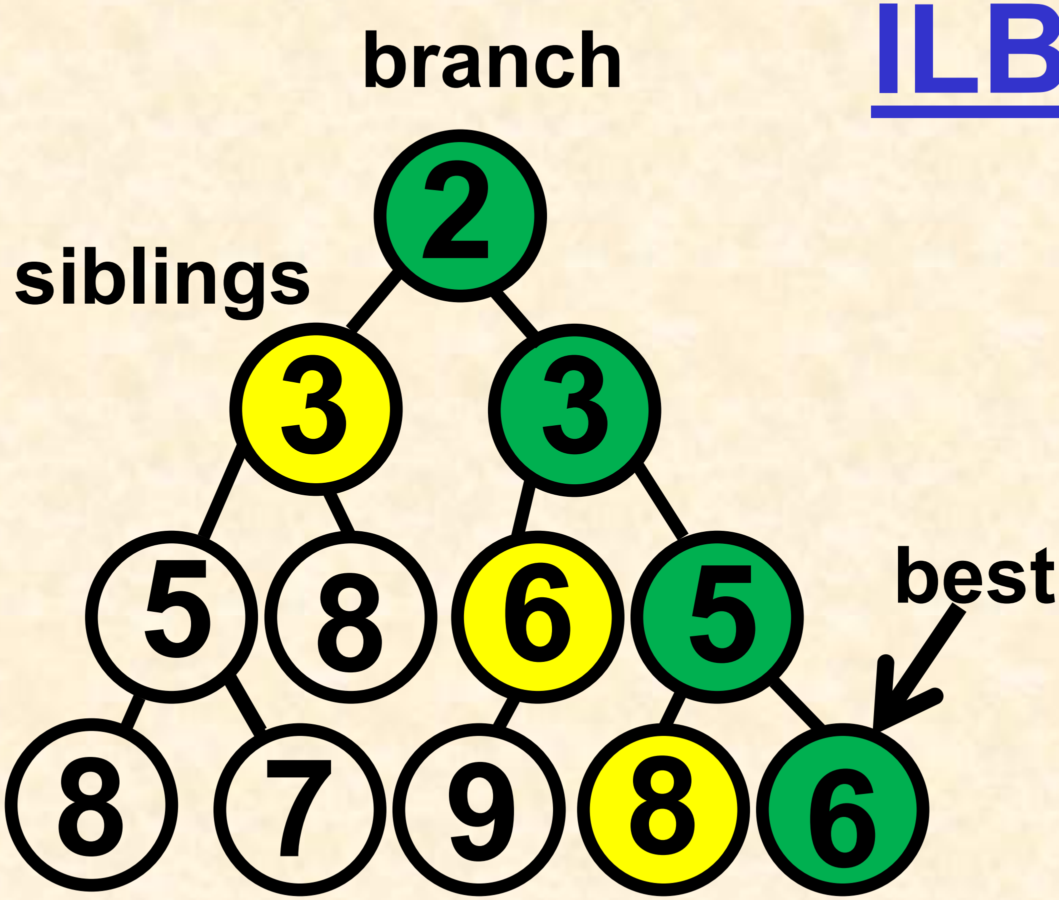

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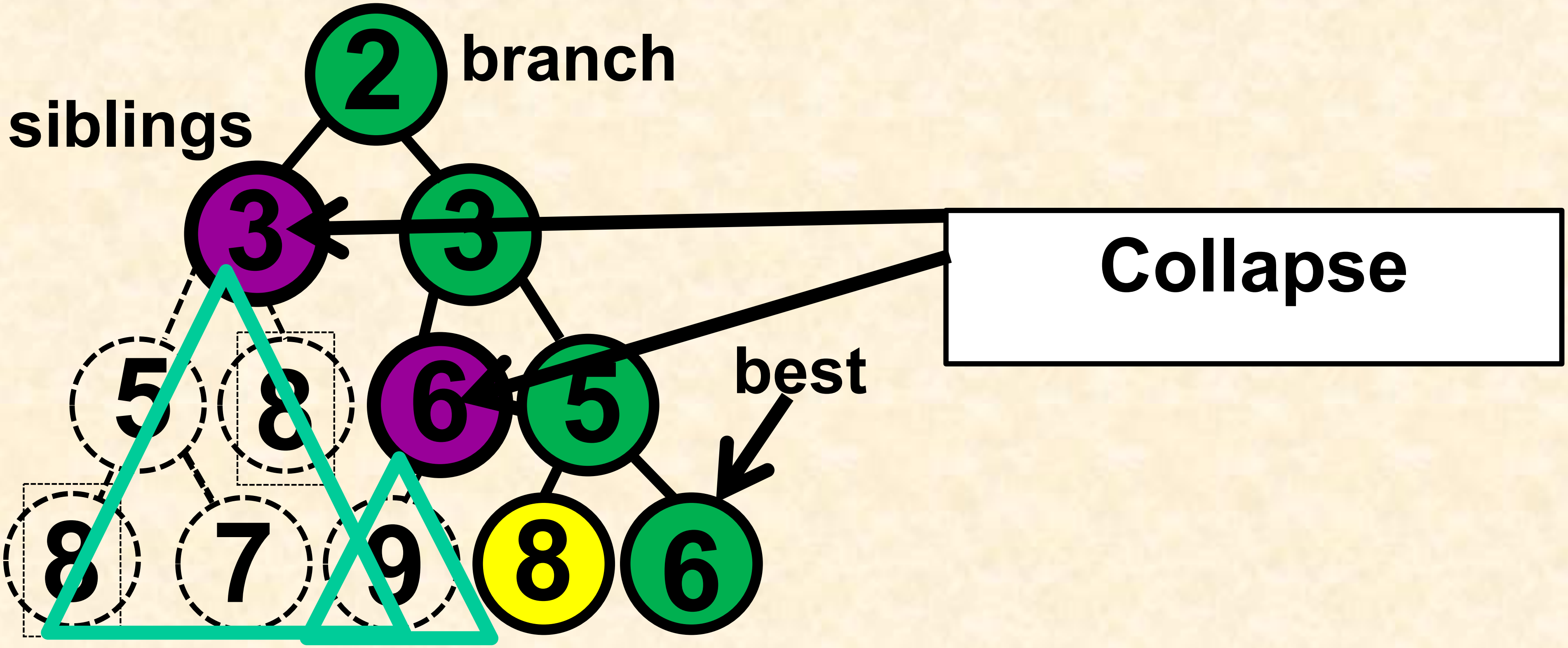

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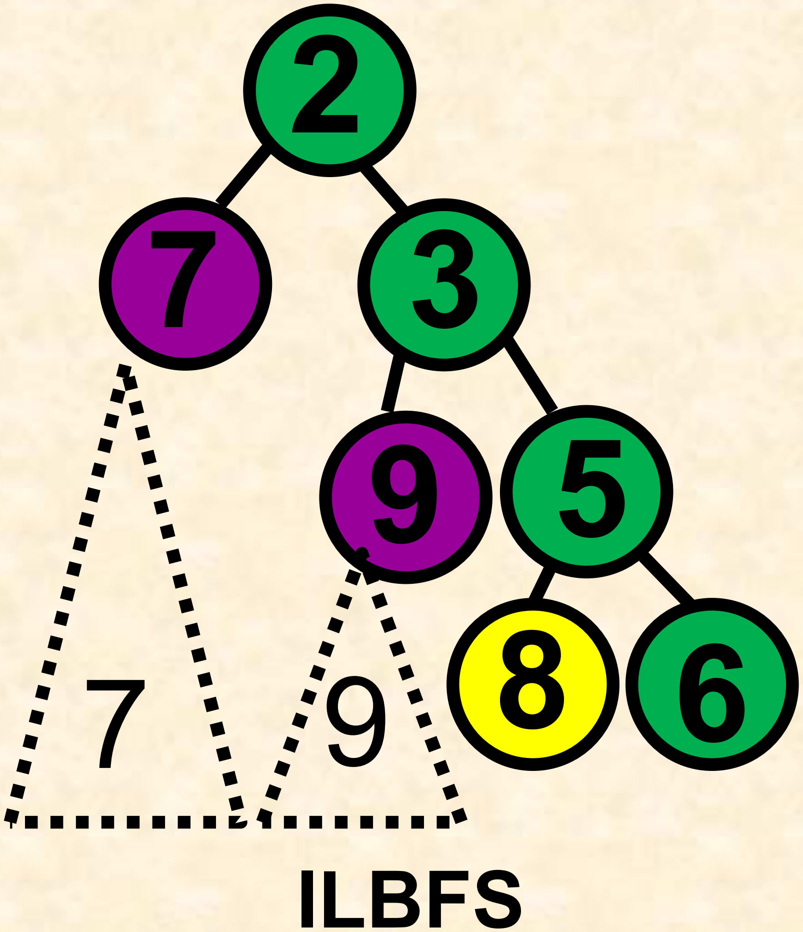
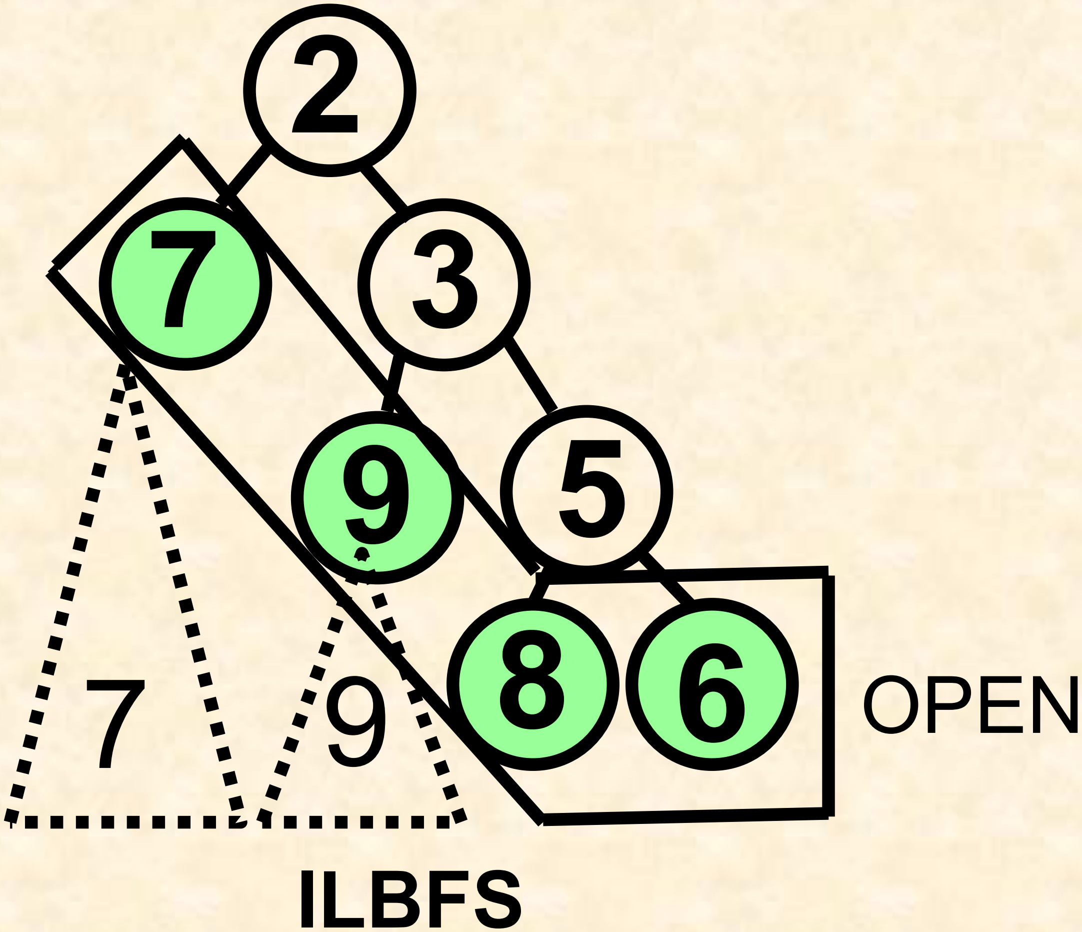
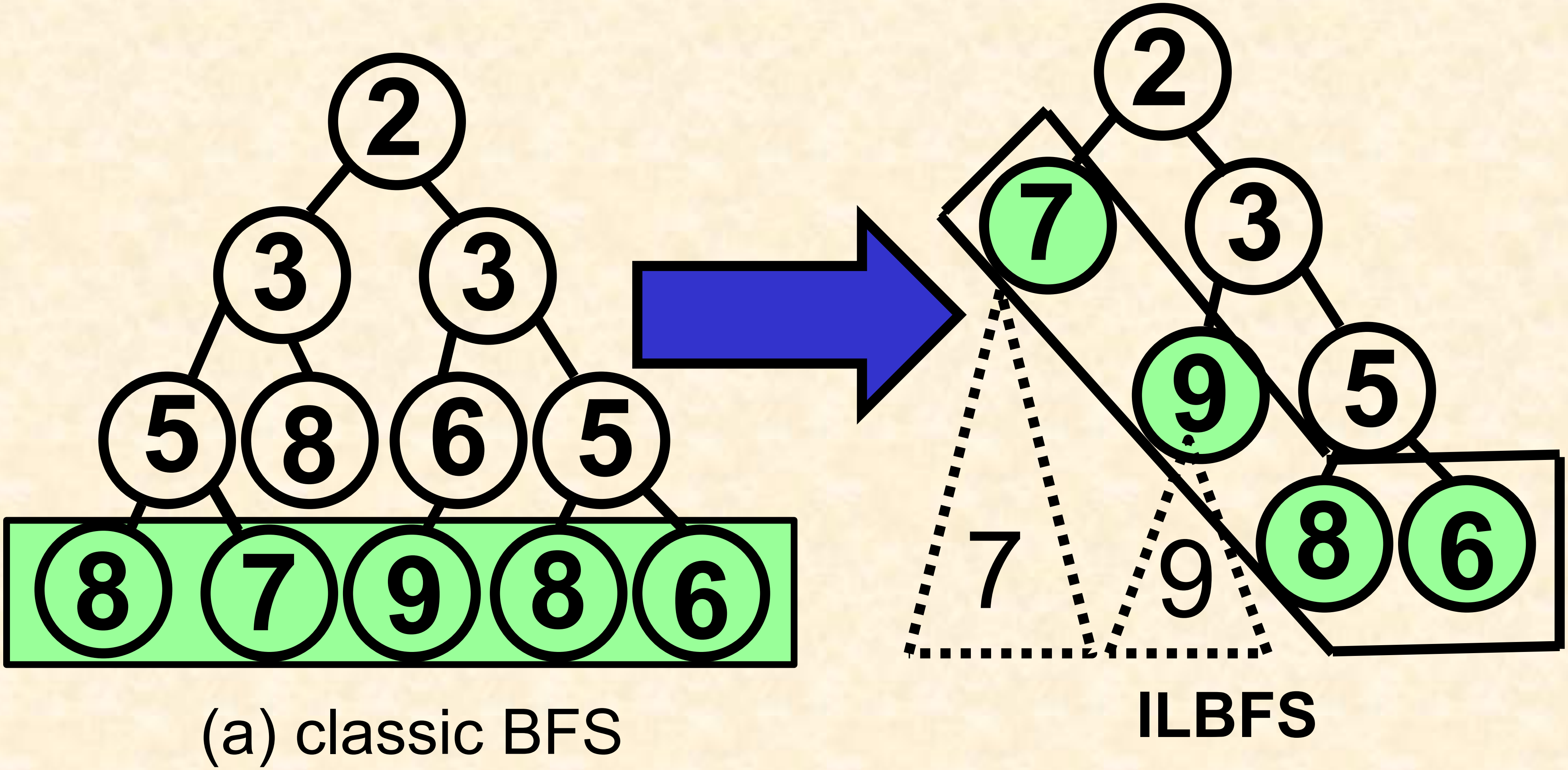


ILBFS



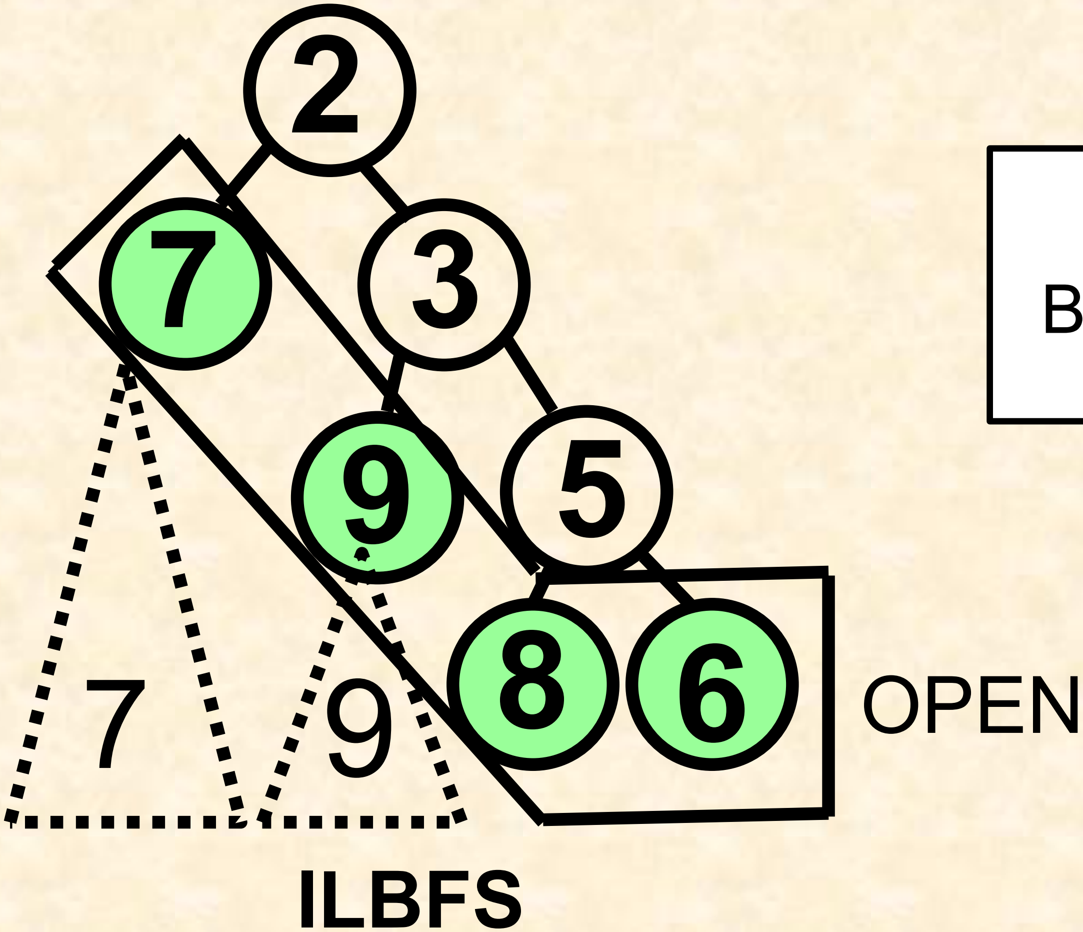
ILBFS



Principal branch invariant

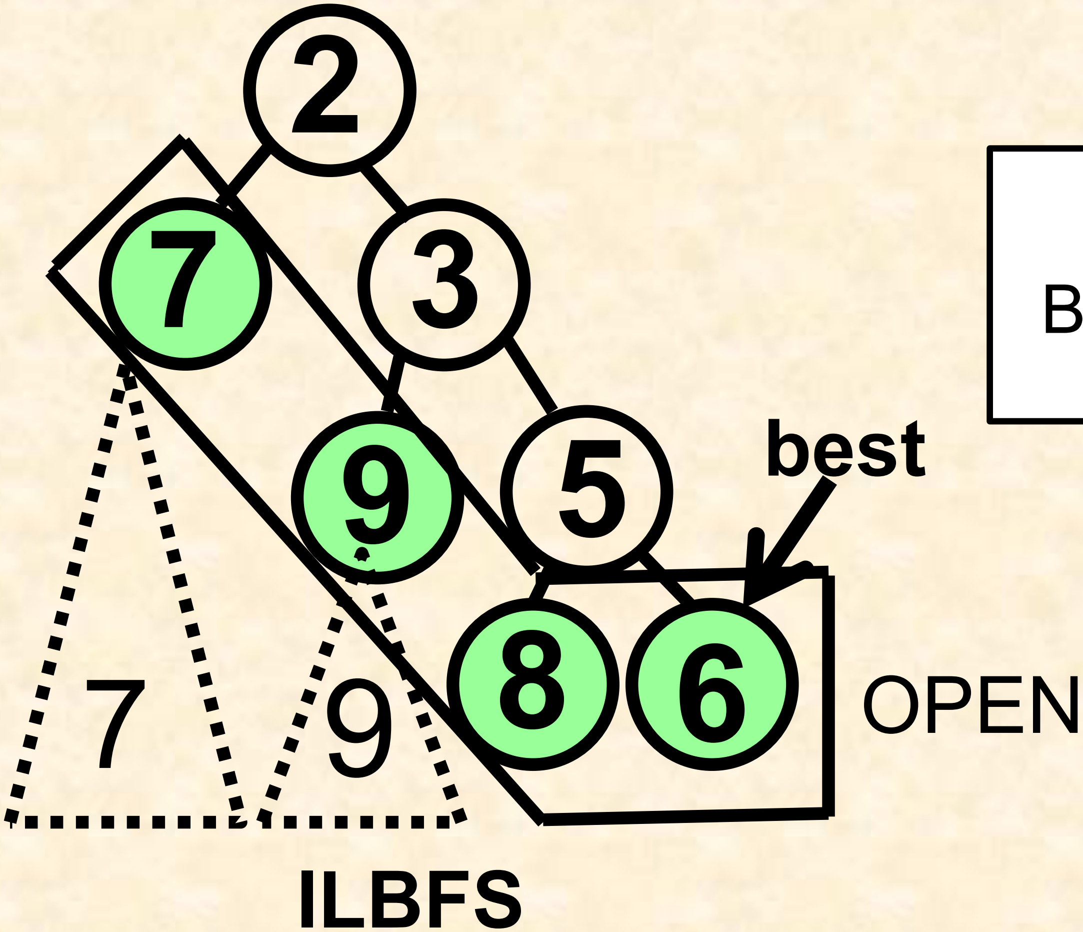
- Initially valid for the root
- Two cases for the expansion cycle.

ILBFS



Case 1:
Best is a child of oldbest

ILBFS



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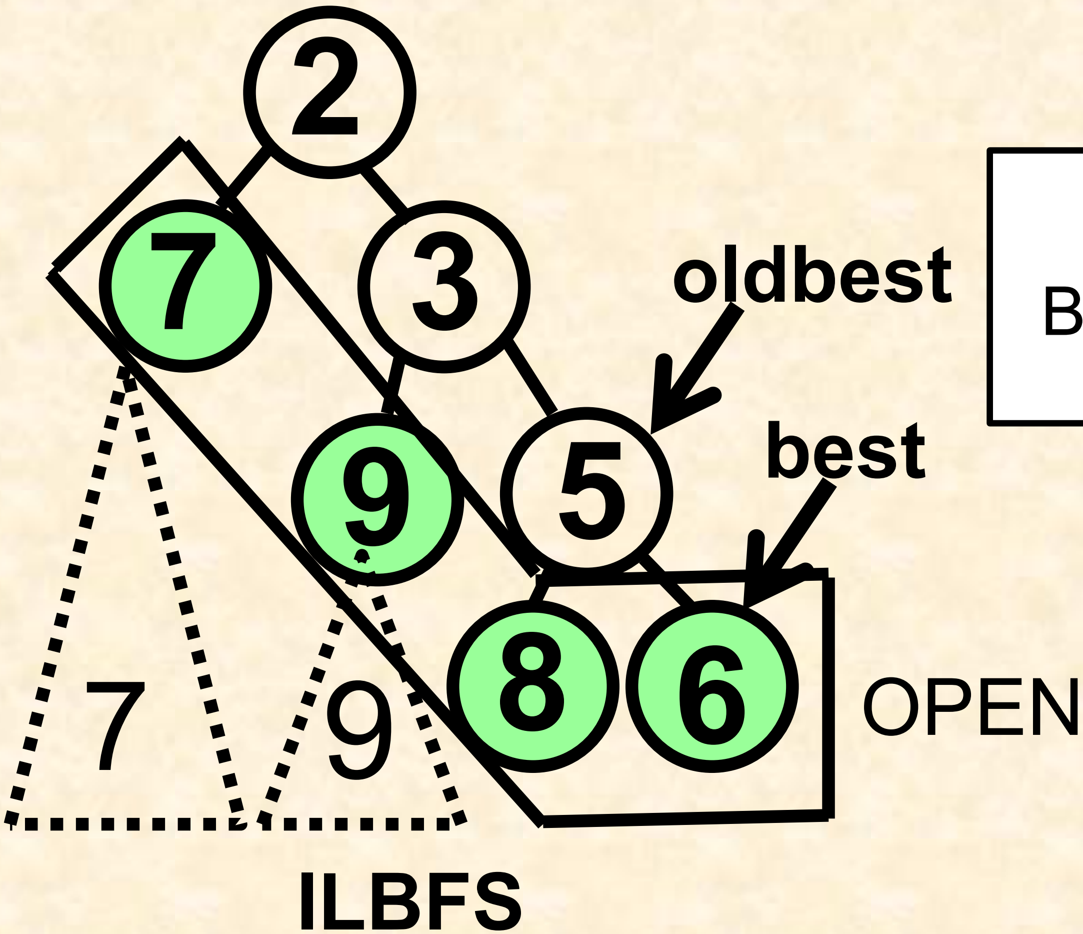

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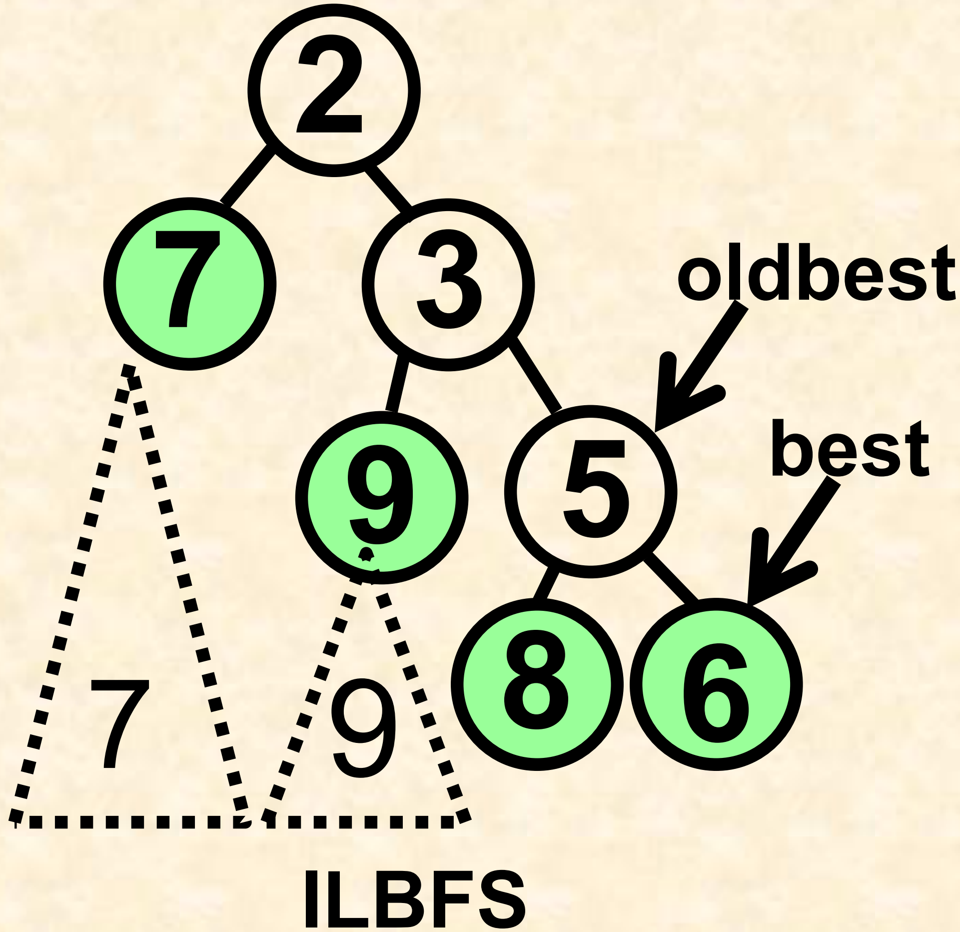

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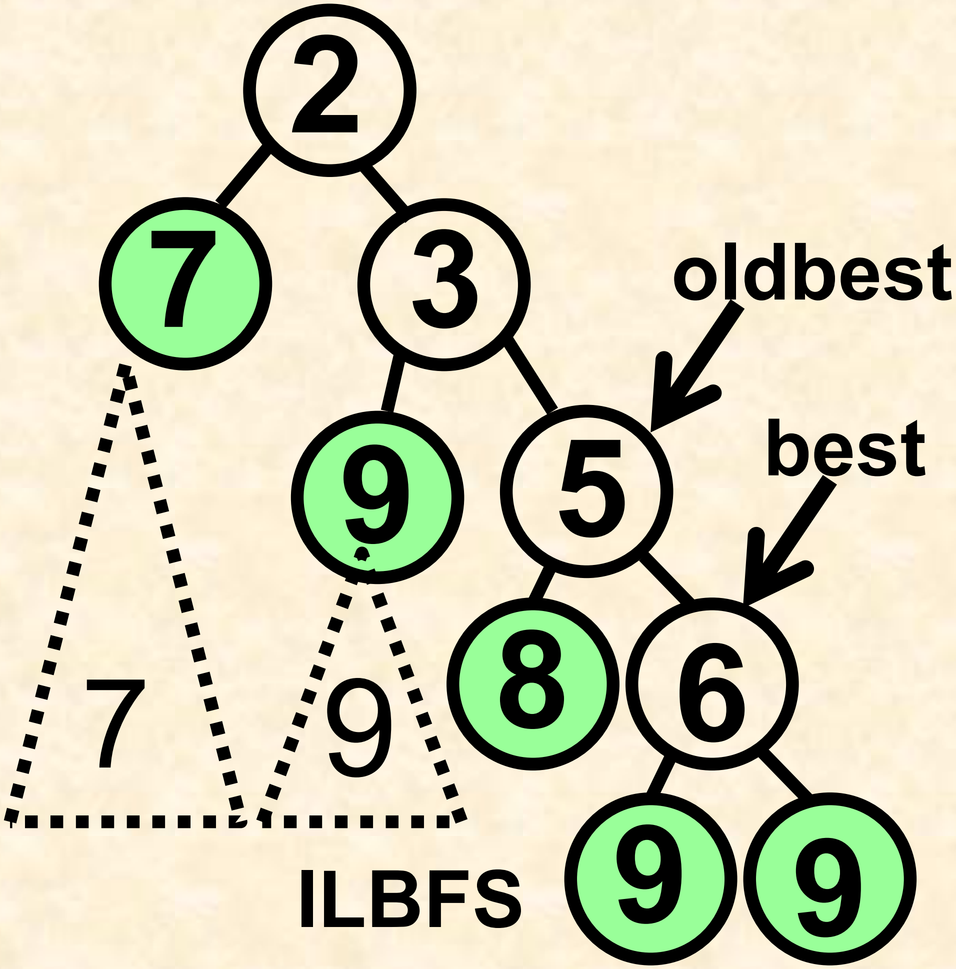

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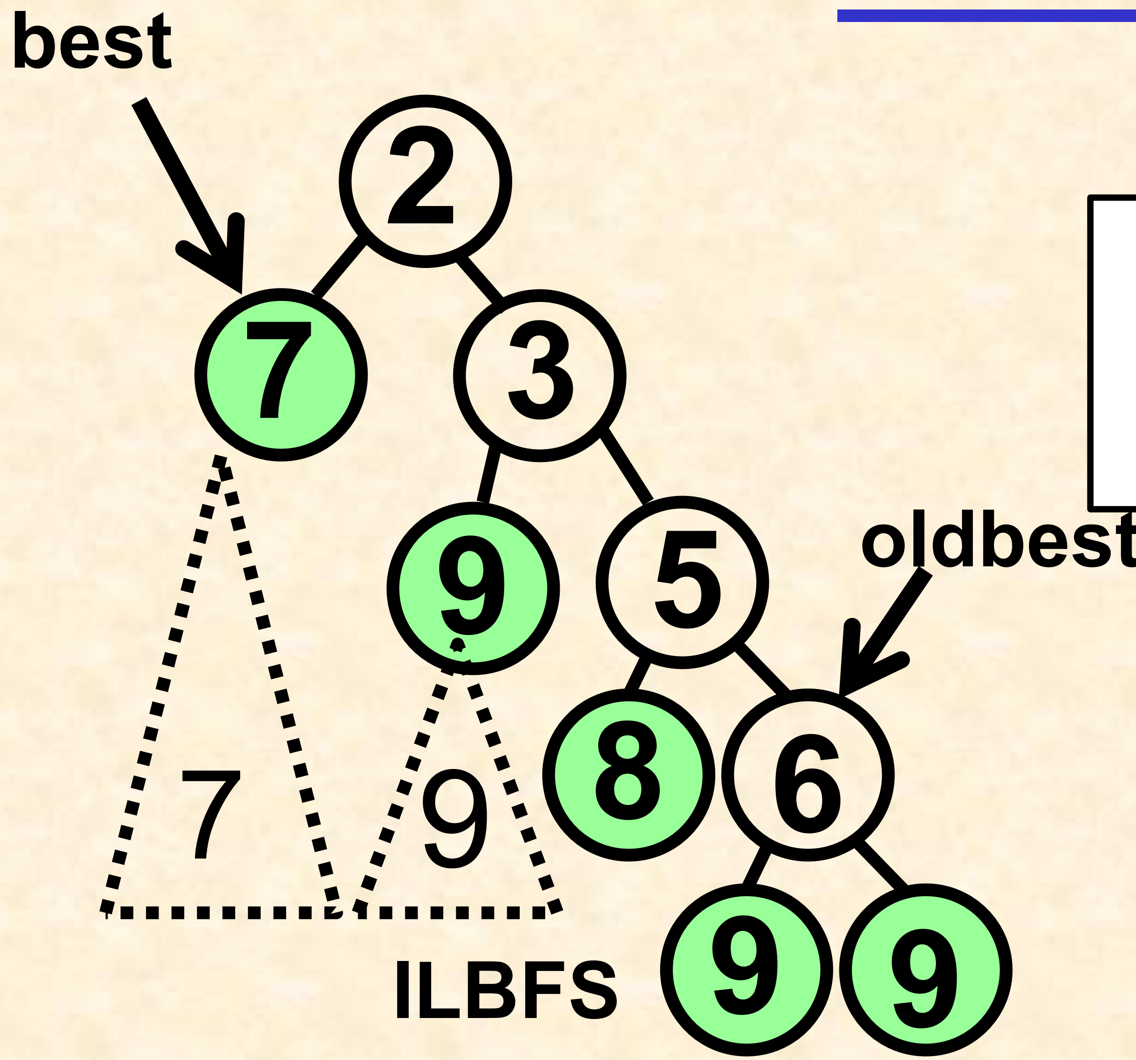
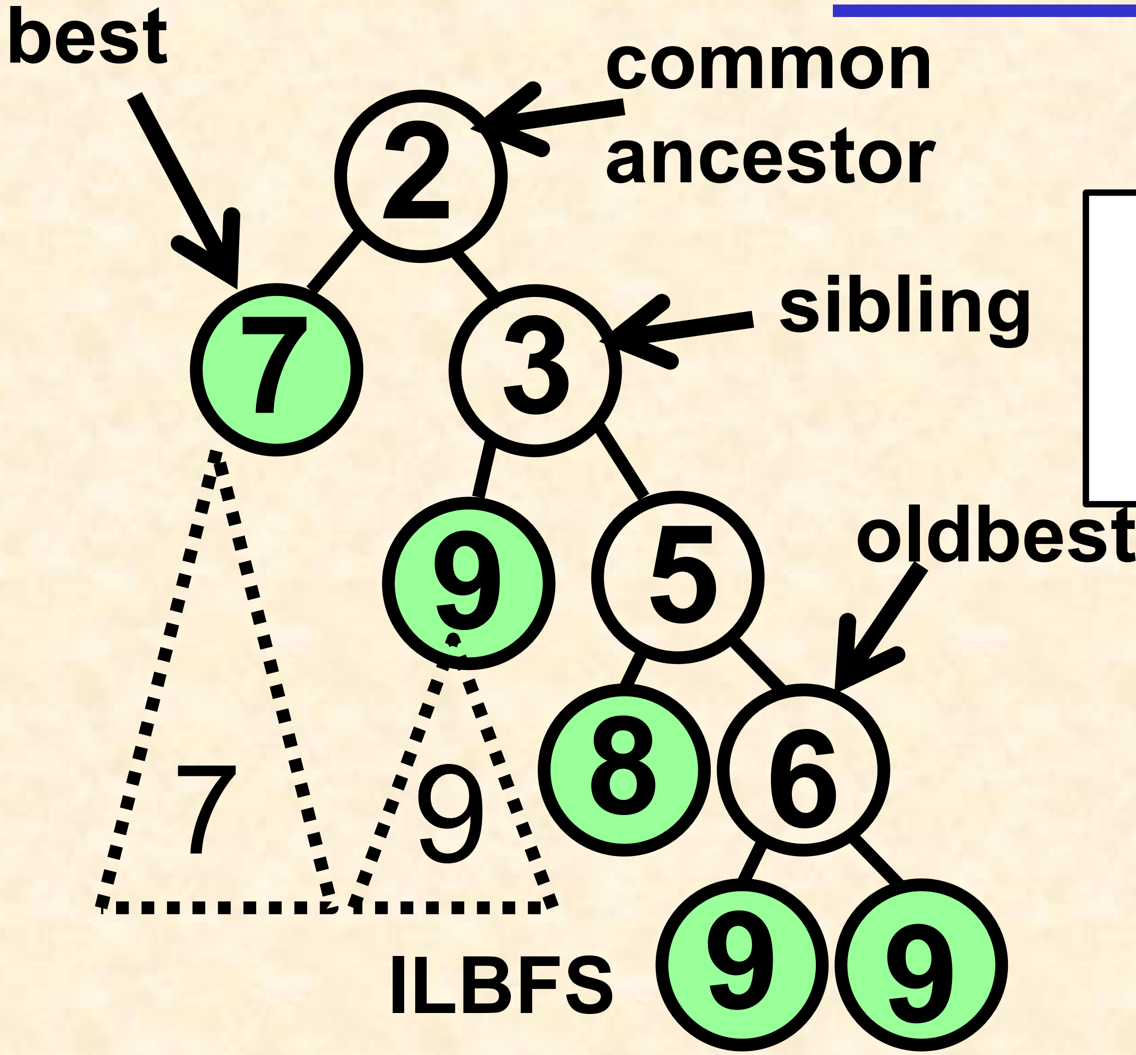


Case 2:

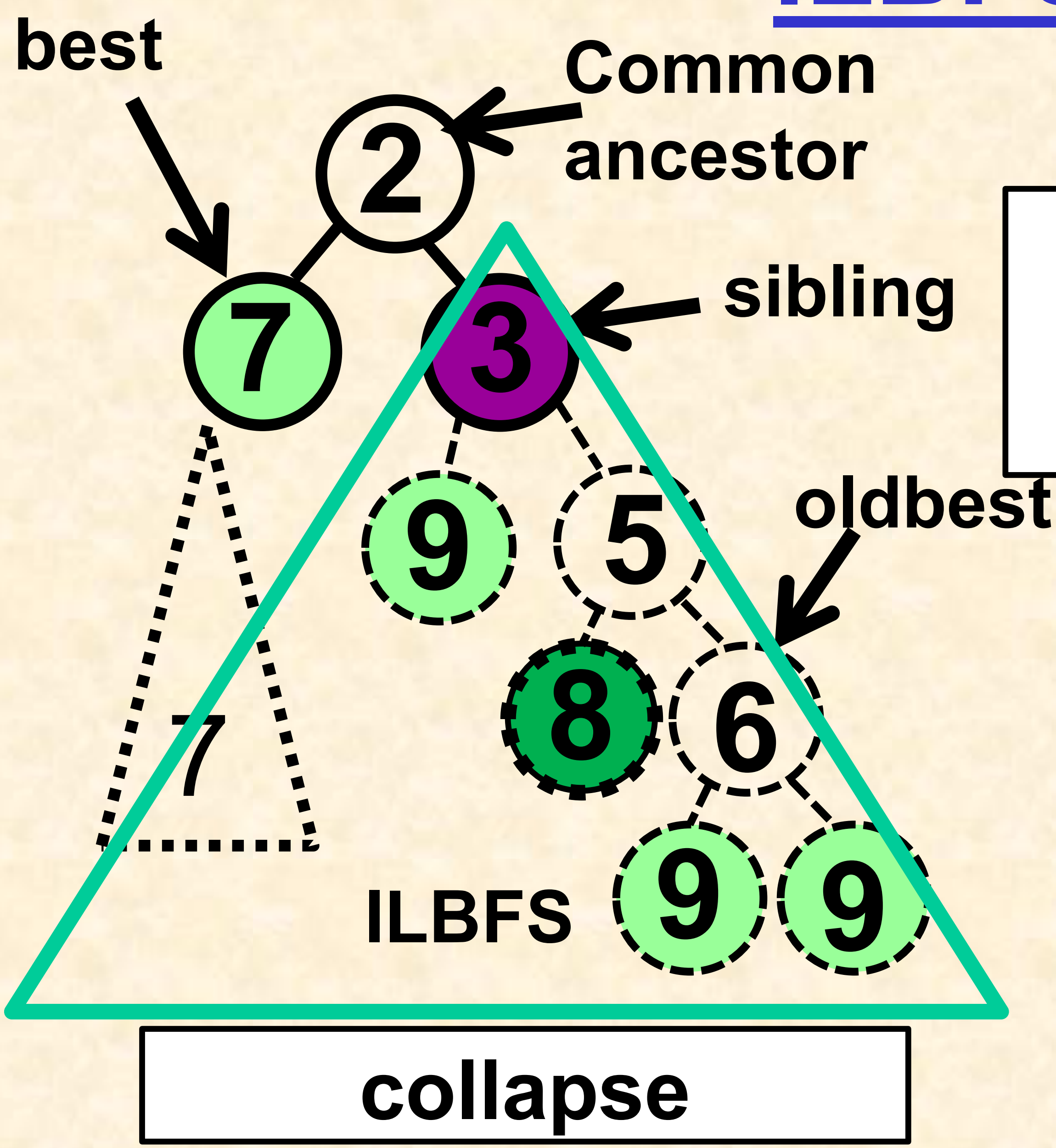
Best is not a child of oldbest

ILBFS



Case 2:
Best is not a
child of oldbest

ILBFS



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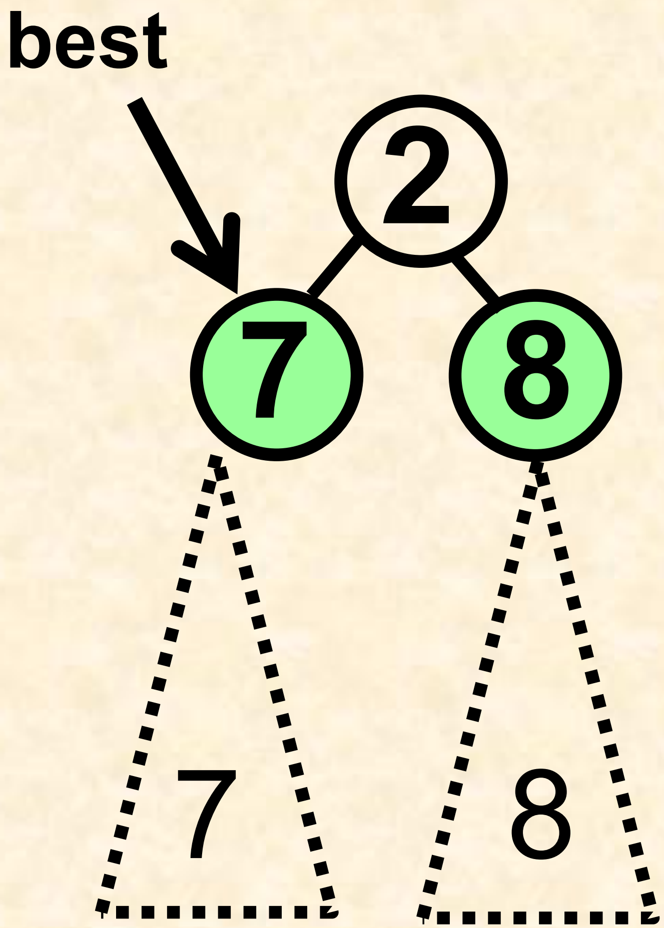
ILBFS



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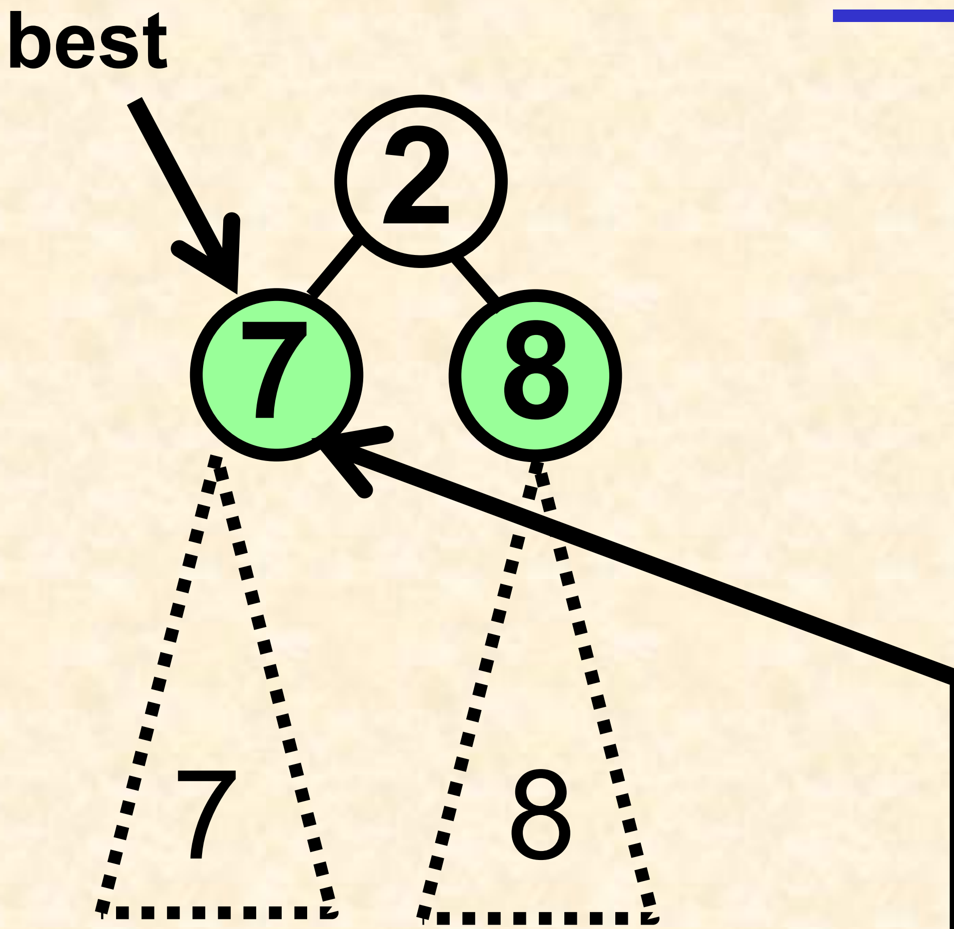
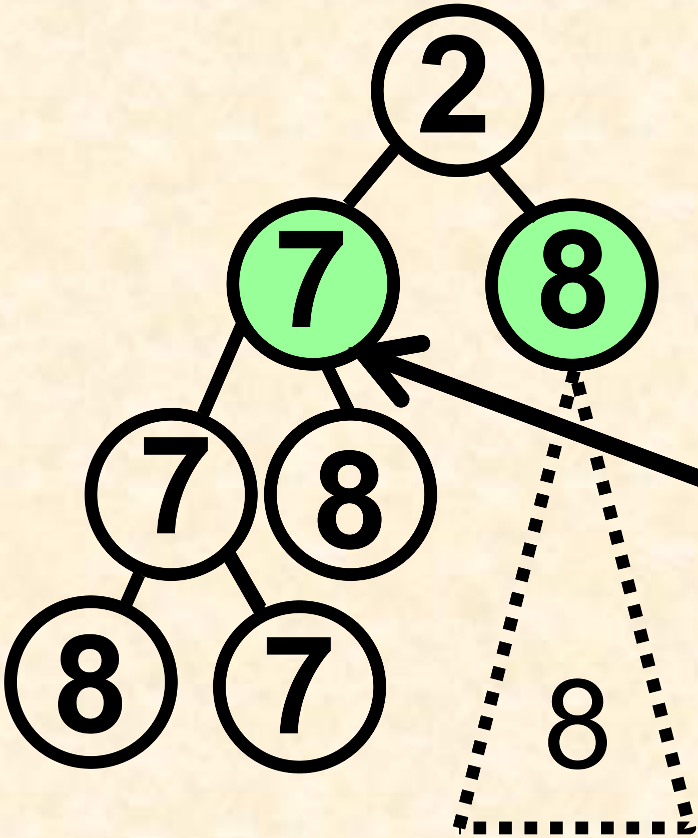


Case 2:
Best is a collapsed node

Restore
f=3, F=7
DFS(7)

ILBFS



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Best is a collapsed node

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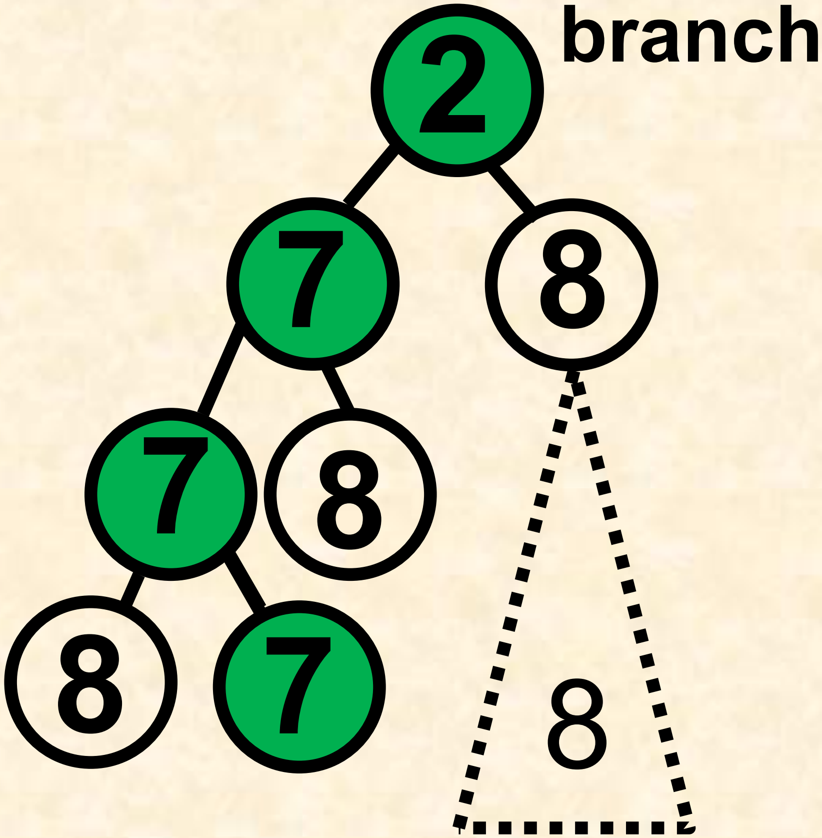
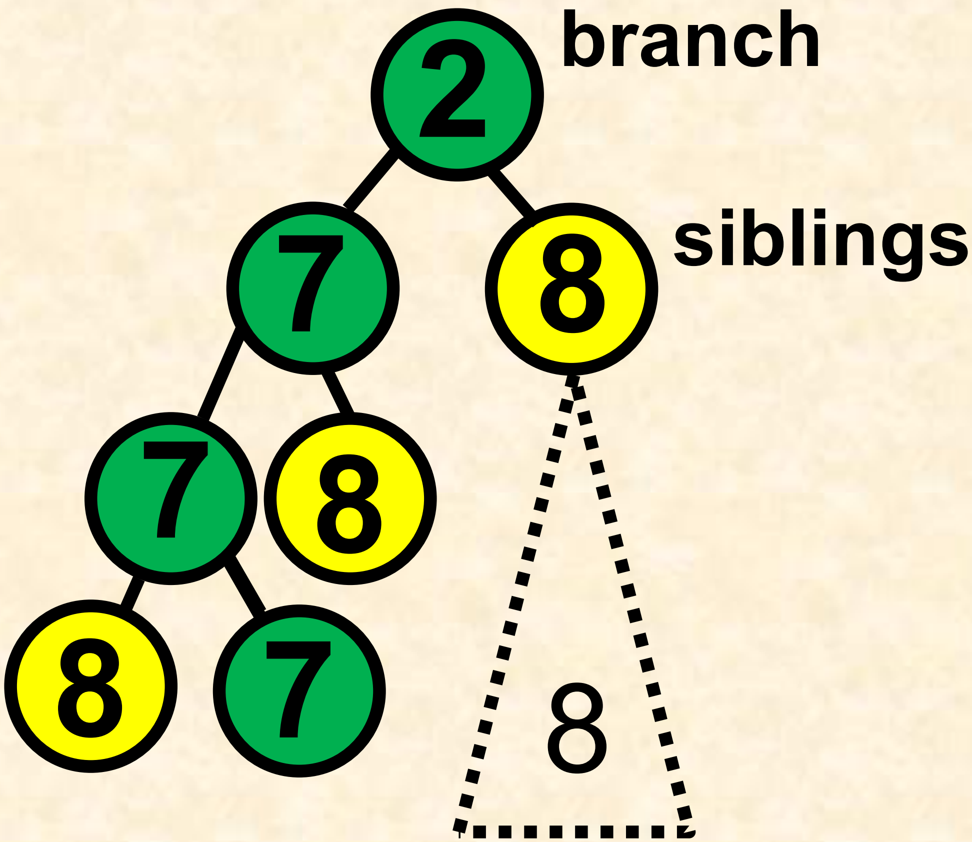
ILBFS



Case 2:

Best is a collapsed node

ILBFS



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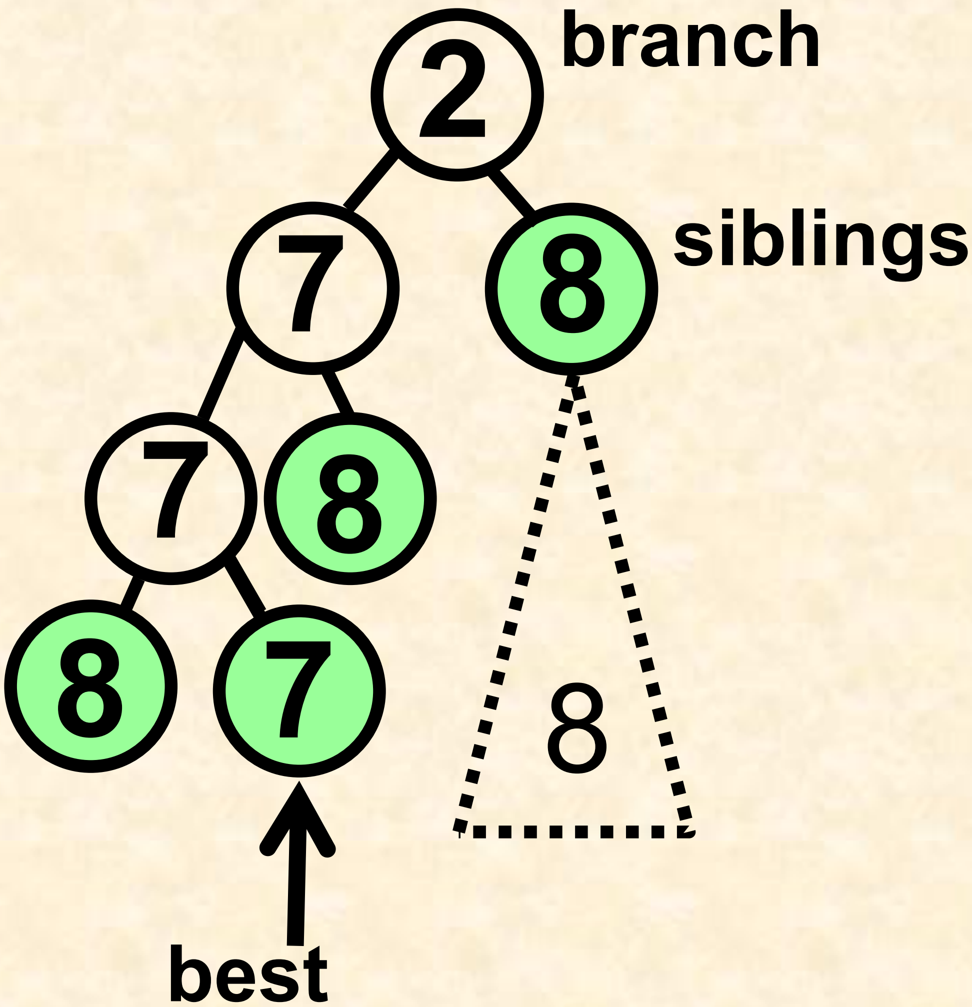


Case 2:

Best is a collapsed node

Restore in ILBFS

- Restore is the only non-trivial step of ILBFS (and RBFS too)

- Observation: After collapse F(n) > f(n)

- Restore: DFS below n bounded by F(n)

Linear-space best-first search

Iterative variant - ILBFS

Algorithm 1: High-level ILBFS

Input: Root R

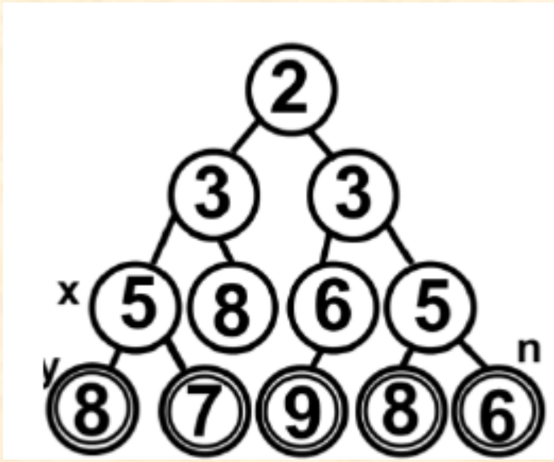
Insert R into OPEN and TREE
oldbest=NULL
while *OPEN not empty* **do**
    best=extract_min(OPEN)
    if *goal(best)* **then**
        exit
    if $oldbest \neq best.parent$ **then**
        $B \leftarrow$ sibling of $oldbest$ that is ancestor of $best$
        collapse(B)
    if $best.C$=$True$ **then**
        $best \leftarrow$ restore($best$)
    foreach *child* C *of best* **do**
        Insert C to OPEN and TREE
    $oldbest \leftarrow best$

Recursive variant - RBFS

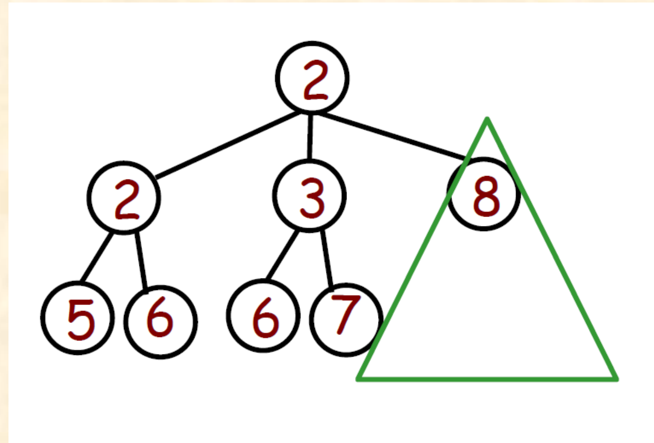
RBFS(n, B)
1. if n is a goal
2. $solution \leftarrow n$; exit()
3. $C \leftarrow expand(n)$
4. if C is empty, return ∞
5. for each child n_i in C
6.   if $f(n) < F(n)$ then $F(n_i) \leftarrow max(F(n), f(n_i))$
7.   else $F(n_i) \leftarrow f(n_i)$
8. $(n_1, n_2) \leftarrow best_{\mathrm{F}}(C)$
9. while $(F(n_1) \leq B$ and $F(n_1) < \infty)$
10. $F(n_1) \leftarrow$ RBFS$(n_1, min(B, F(n_2)))$
11. $(n_1, n_2) \leftarrow best_{\mathrm{F}}(C)$
12. return $F(n_1)$

ILBFS – an iterative variant of RBFS [Korf 1993]

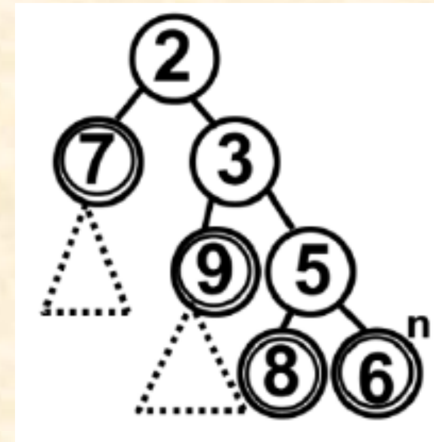
A*



SMA*



RBFS/ILBFS



memory	b^d	*M*	*O(d)*
collapse	never	lazily	eagerly

continuum