T182 - Cave Exploration

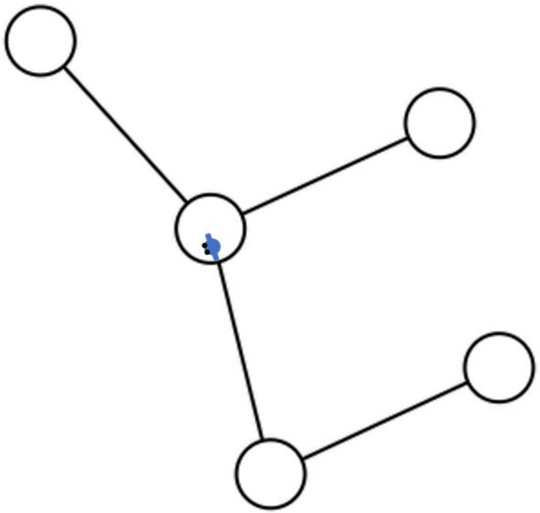
Percy Wong {percywtc}

The Problem

You are at some node of an unknown tree

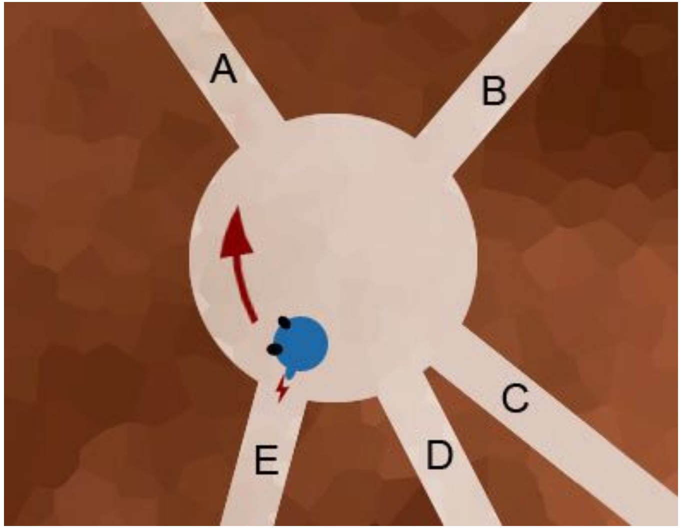
You have to find out the structure of this tree by:

- Walking through the corridors
- Placing and removing flags



The Problem

- `void reportCorridor(int x)`
  - He will enter corridor A if x = 1, 6, 11, ...
  - He will enter corridor B if x = 2, 7, 12, ...
  - He will enter corridor C if x = 3, 8, 13, ...
  - He will enter corridor D if x = 4, 9, 14, ...
  - He will enter corridor E if x = 5, 10, 15, ...
- `void placeFlag()`
- `void removeFlag()`
- `int countFlags()`
- `bool detectDeadEnd()`



Statistics

Max	Mean	Std Dev	Subtasks						
100	39.641	28.911	13: 35	14: 28	17: 19	11: 12	8: 12	22: 4	15: 4

Difficulties?

- You don’t even know where you (or Robo) are
- You don’t even know how many corridors in a room
  - so you can’t go back to the room you just come from easily

So the task seems impossible?!

Difficulties?

So the task seems impossible?!

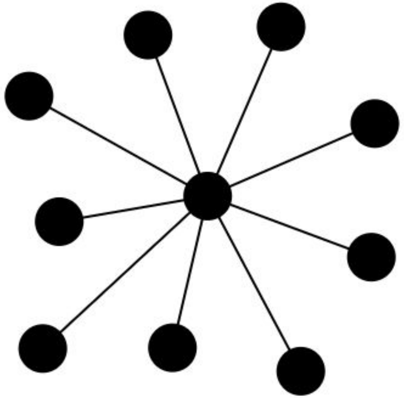
We should learn from the subtasks!

Subtask 1

It is given that the tree is “star-shape”

So our only possible initial positions are:

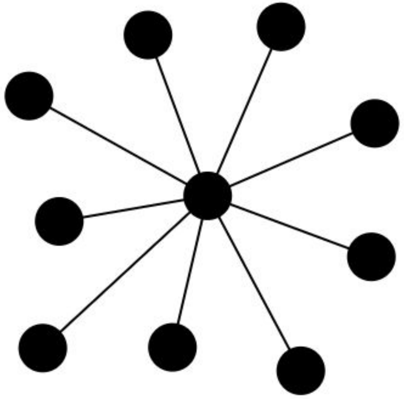
- at the centroid
- at one of the leaves



Subtask 1

The first crucial observation

- if we keep performing `chooseCorridor(1)`
- we can walk through the whole star
- why?



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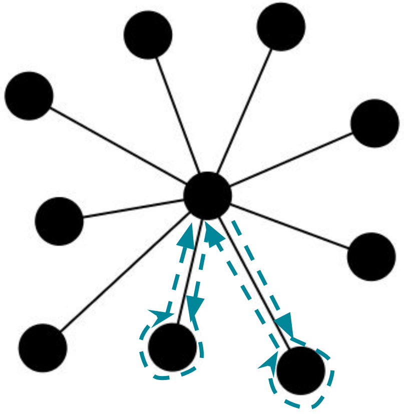


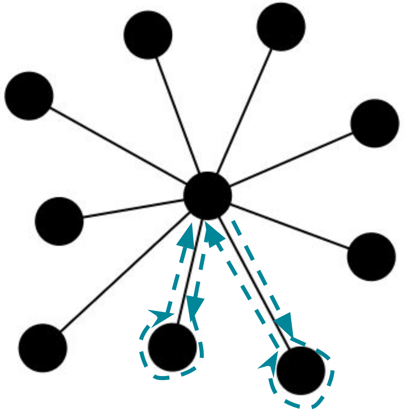
Subtask 1

The first crucial observation

- if we keep performing `chooseCorridor(1)`
- we can walk through the whole star

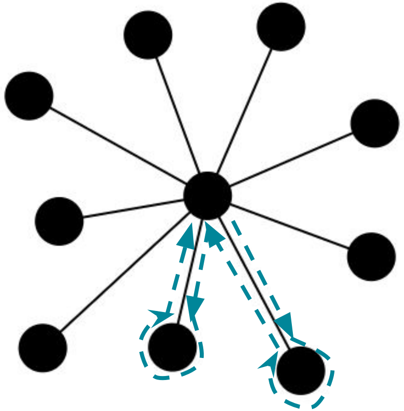
So we can actually do something like

- keep walking by performing `chooseCorridor(1)`
- mark the node as `visited` if `not visited` before
- maintain `visited` by `placeFlag()` and `countFlags()`
- count the number of nodes is sufficient



Subtask 1

```
do 60000 times: // you can actually reduce iterations
  chooseCorridor(1)
  if (countFlags() == 0) // meaning not visited
    placeFlag()
    treeSize++
```



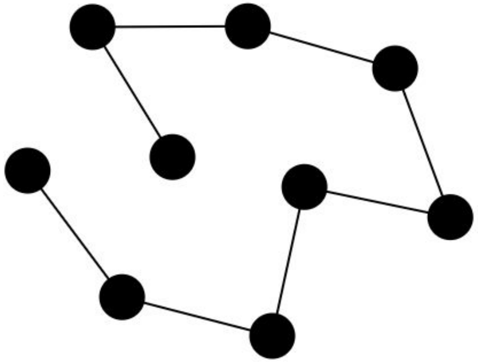
```
treeSize
1 2
1 3
…
1 treeSize
```

Subtask 2

It is given that the tree is “star-shape” or “chain-shape”

Is the observation in “star-shape” true in “chain-shape”?

- if we keep performing `chooseCorridor(1)`
- we can walk through the whole chain
- why?



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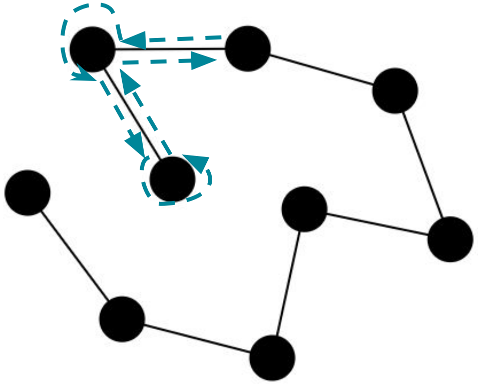

Subtask 2

Is the observation in “star-shape” true in “chain-shape”?

- if we keep performing `chooseCorridor(1)`
- we can walk through the whole chain

So we can actually do this again:

- keep walking by performing `chooseCorridor(1)`
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Subtask 2

But then, how to determine if the cave is “star” or “chain”?

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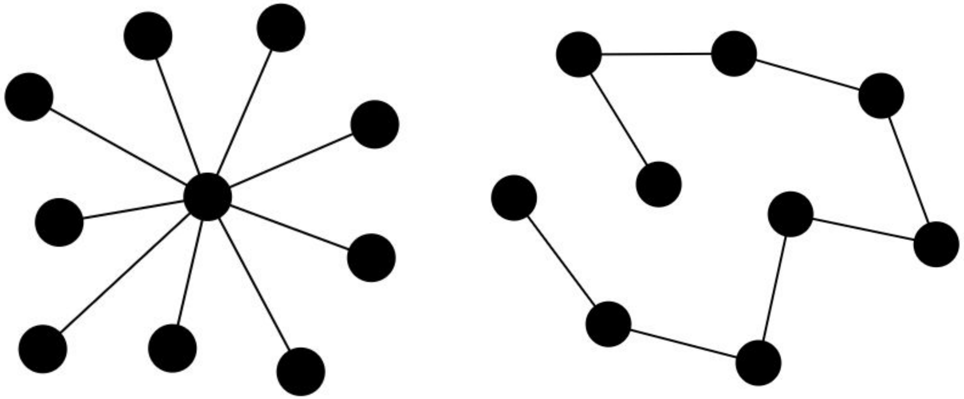
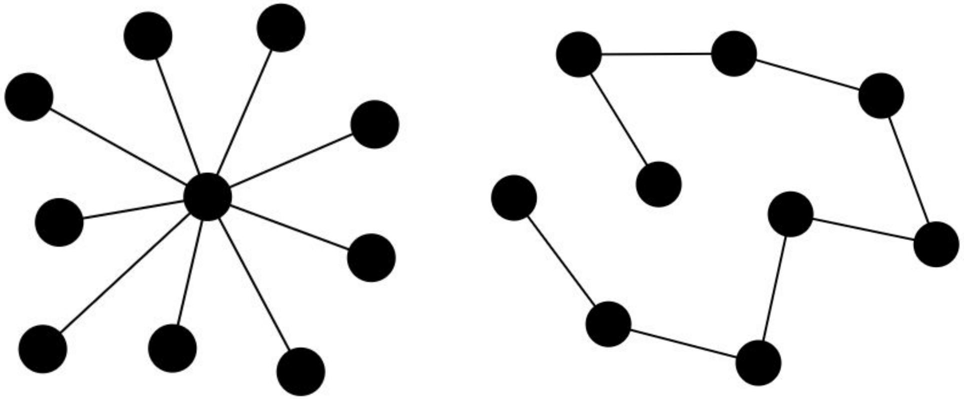
We can make use of `detectDeadEnd()`

- “star” has many dead-ends
- “chain” has exactly two



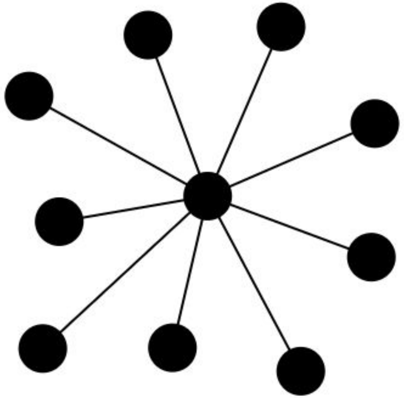
Subtask 2

```
do 60000 times: // you can actually reduce iterations
  chooseCorridor(1)
  if (countFlags() == 0) // meaning not visited
    placeFlag()
    treeSize++
    if (detectDeadEnd())
      deadEndCount++
```

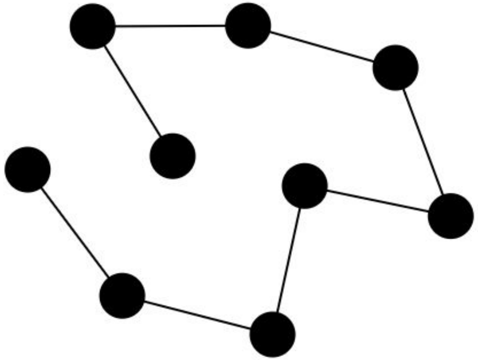


Subtask 2

```
deadEndCount > 2

N
1 2
1 3
…
1 N
```



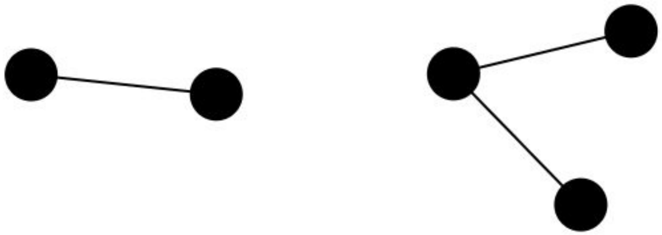
```
deadEndCount == 2

N
1 2
2 3
…
N-1 N
```



Subtask 2

Be careful with these two cases

- they have the properties of both “star-shape” and “chain-shape”



Subtask 3 - 7

From now on, the cave can be any tree

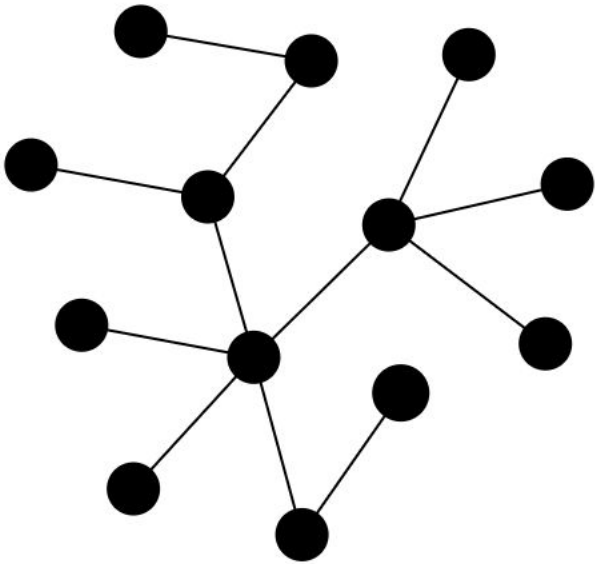
- Subtask 3 - 5: **F** is quite large
- Subtask 6 - 7: **F** is only **2**, perhaps expecting a different solution

3	17	$maxN = 100$, $L = 60000$, $F = 10000$, $D = \text{true}$
4	11	$maxN = 100$, $L = 60000$, $F = 1000$, $D = \text{true}$
5	8	$maxN = 100$, $L = 60000$, $F = 100$, $D = \text{true}$
6	22	$maxN = 100$, $L = 60000$, $F = 2$, $D = \text{true}$
7	15	$maxN = 100$, $L = 30000$, $F = 2$, $D = \text{false}$

Subtask 3 - 7

The crucial crucial crucial observation again again again

- if we keep performing `chooseCorridor(1)`
- we can walk through the whole tree
- the behaviour is exactly the same as:
    - running DFS
    - Euler Tour



Subtask 3 `// L = 60000, F = 10000, D = true`

With **F = 10000**, we can actually number the nodes with flags

- each time reaching a node, check if it's new by `countFlags() == 0`
- if it's new, instead of putting ONE flag, put a new unused number
- for reaching the **k**-th new node, place **k** flags

- so nodes have label now
- by maintaining the label before and after `chooseCorridor()`
- we can easily output the tree

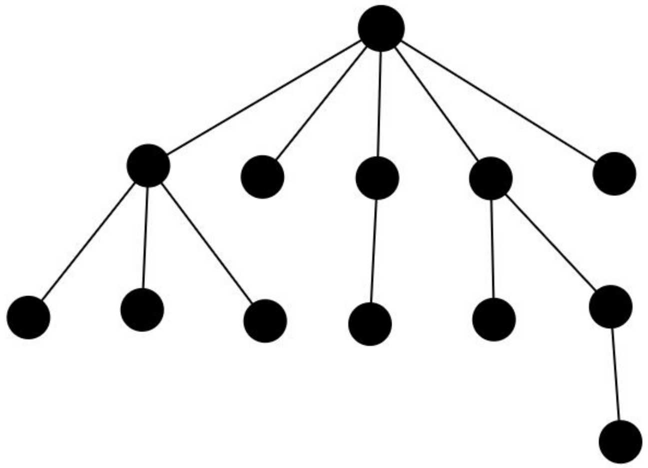
Subtask 3 // `L = 60000, F = 10000, D = true`

consider the tree is rooted, with our initial position as the root

after calling `chooseCorridor(1)`

- if `countFlags() == 0`, we reach a new node
  - increase **N** by 1
  - place **N** flags on this node to label it
  - memorize this edge, between `parent` and `current`

requires at most `1+2+3+...+100 = 5050` flags



Subtask 4 // `L = 60000, F = 1000, D = true`

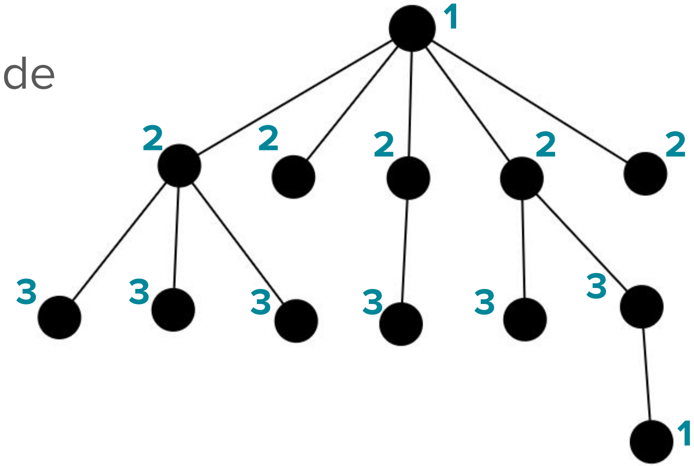
5050 flags == too many

we can optimize it by only memorizing the `depth % 3`

still able to know where is our current position by

- comparing the label of previous and current node
- if (`3->2 || 2->1 || 1->3`), we go up
- if (`3->1 || 2->3 || 1->2`), we go down

requires at most `1+2+3+...+3 = 297` flags



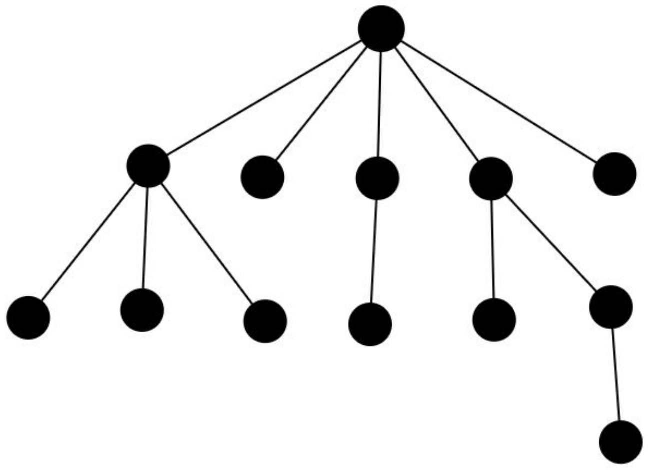
Subtask 5 // `L = 60000, F = 100, D = true`

297 flags == still too many

after calling `chooseCorridor(1)`

- if `countFlags() != 0`, we back to parent
  - we are able to know our current position
- if `countFlags() == 0`, we reach a new node
  - increase **N** by 1
  - place ~~**N flags**~~ **ONE flag** on this node to mark visited
- we are still able to know our current position

requires at most `1+1+...+1 = 100` flags



Subtask 6 - 7 // F = 2

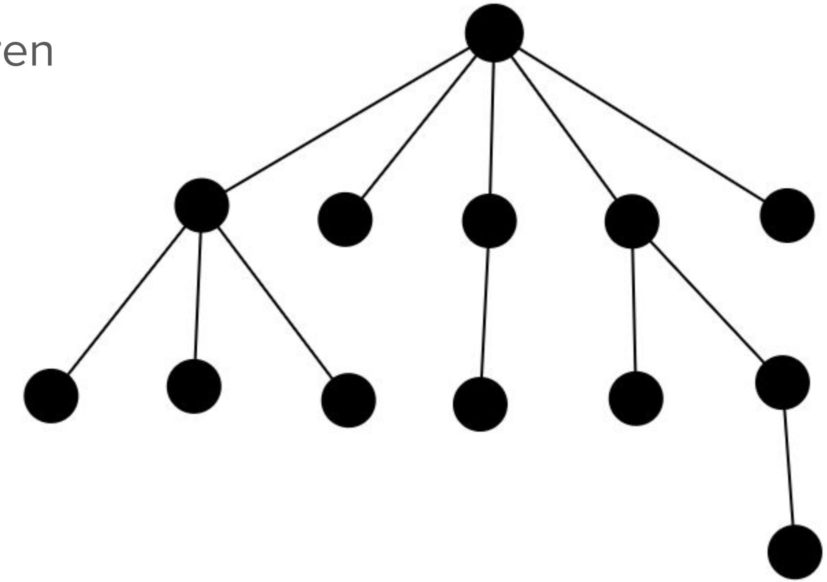
Subatsk 6 - 7 are with extremly small **F**, expecting a very different solution

3	17	$maxN = 100$, $L = 60000$, $F = 10000$, $D = \text{true}$
4	11	$maxN = 100$, $L = 60000$, $F = 1000$, $D = \text{true}$
5	8	$maxN = 100$, $L = 60000$, $F = 100$, $D = \text{true}$
6	22	$maxN = 100$, $L = 60000$, $F = 2$, $D = \text{true}$
7	15	$maxN = 100$, $L = 30000$, $F = 2$, $D = \text{false}$

Subtask 6 // `L = 60000, F = 2, D = true`

with only 2 flags, what can we do? the idea is

- for each node, find the number of children
- do this recursively



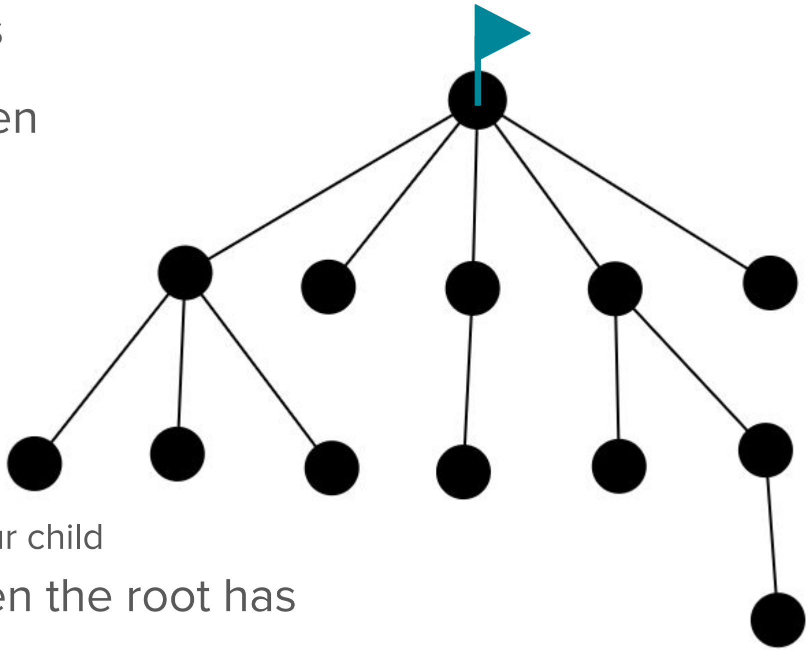
Subtask 6 `// L = 60000, F = 2, D = true`

with only 2 flags, what can we do? the idea is

- for each node, find the number of children
- do this recursively

if we place a flag at the root

- keep running `chooseCorridor(1)`
- when we meet `countFlags() == 1`
  - we back to the root
  - meaning we walked through the subtree of our child
- but we still don't know how many children the root has

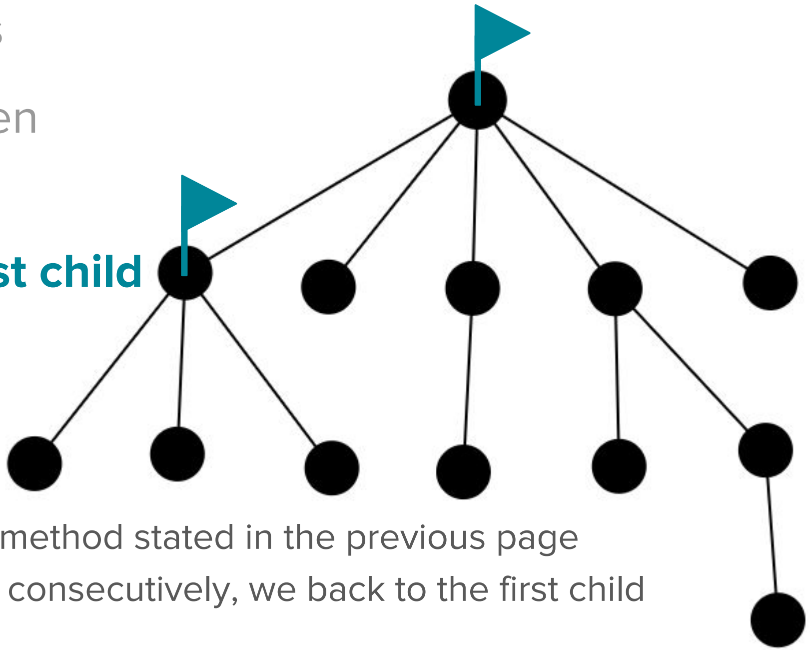


Subtask 6 // `L = 60000, F = 2, D = true`

with only 2 flags, what can we do? the idea is

- for each node, find the number of children
- do this recursively

if we place a flag at the root, **and also the first child**



- when we meet `countFlags() == 1`
  - we back to the ~~**root**~~ **first child**
- continue to run `chooseCorridor(1)`
  - we can count the number of children with the method stated in the previous page
  - when we encounter `countFlags() == 1` twice consecutively, we back to the first child

Subtask 6 // `L = 60000, F = 2, D = true`

with only 2 flags, what can we do? the idea is

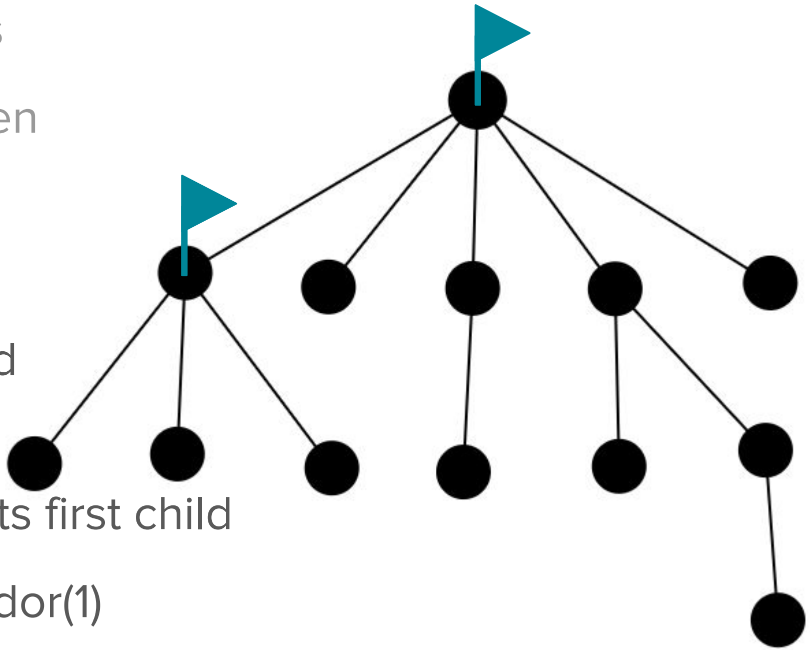
- for each node, find the number of children
- do this recursively

for nodes other than the root

- we incorrectly count the parent as a child
- so just delete the last child found

as everytime after solving a node, we are at its first child

- we can go back by running chooseCorridor(1)
- until it reaches the first child



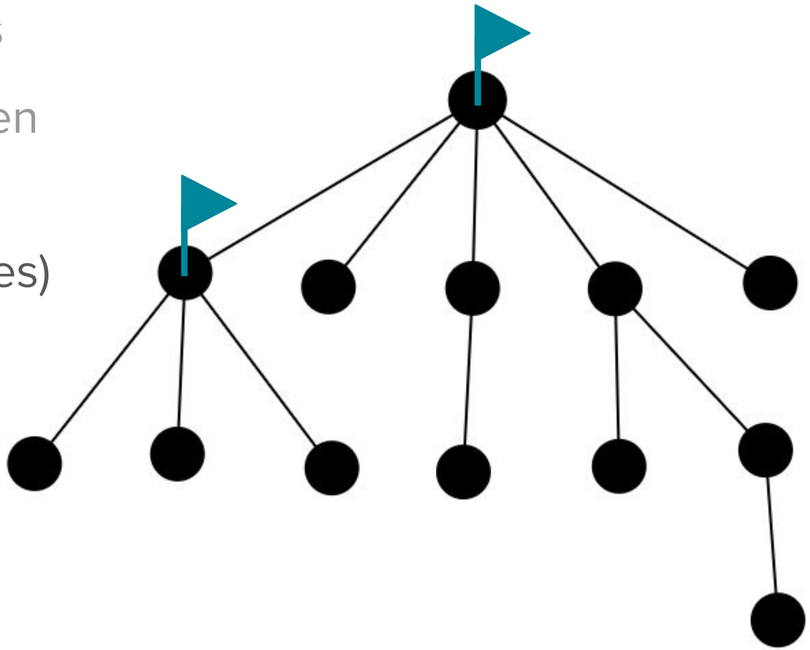
Subtask 6 `// L = 60000, F = 2, D = true`

with only 2 flags, what can we do? the idea is

- for each node, find the number of children
- do this recursively

have to carefully handle the dead-ends (leaves)

- especially when the first child is a leaf
- easiest way: `detectDeadEnd()`



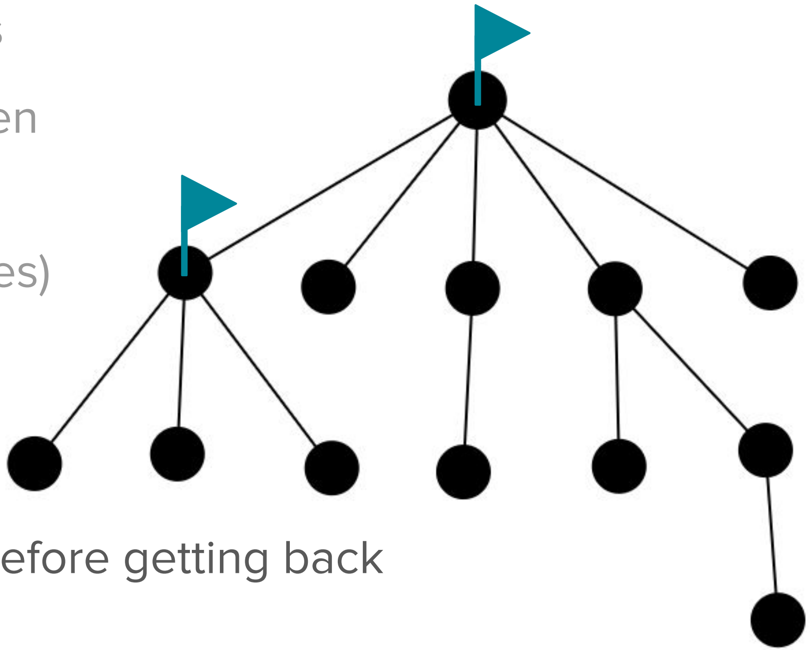
Subtask 7 `// L = 30000, F = 2, D = false`

with only 2 flags, what can we do? the idea is

- for each node, find the number of children
- do this recursively

have to carefully handle the dead-ends (leaves)

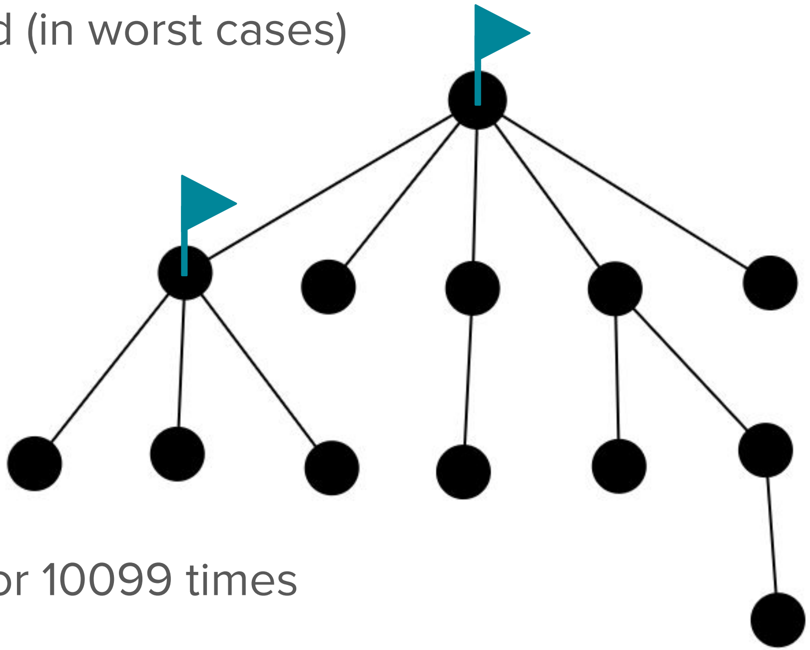
- especially when the first child is a leaf
- ~~easiest way: `detectDeadEnd()`~~
- maintaining subtree size
- by counting `chooseCorridor(1)` called before getting back



Subtask 7 // `L = 30000, F = 2, D = false`

my implementation on this solution has called (in worst cases)

- `chooseCorridor(1)` for 29700 times
- enough to get 100 points :)



if for every non-root nodes

- ~~place the flag at itself and its first child~~
- place the flag at parent and itself
- worst case: calling `chooseCorridor(1)` for 10099 times
- (thanks Steven Lau - `cylau`)