Threaded Binary Trees

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Outline

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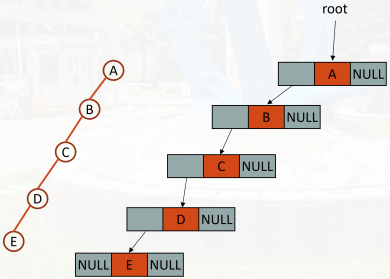
- Number of null non-null links: $n - 1$.
- Number of null links: $n + 1$.



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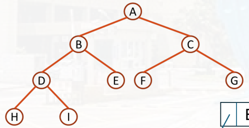
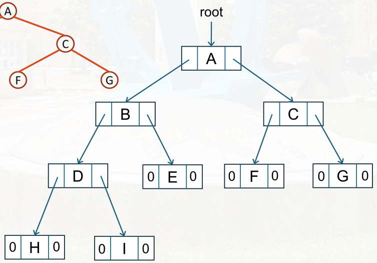
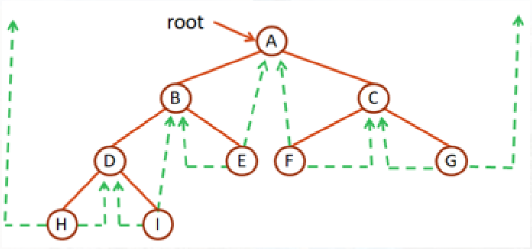




Solution

Replace the NULL links by pointers, threads, pointing to other nodes.



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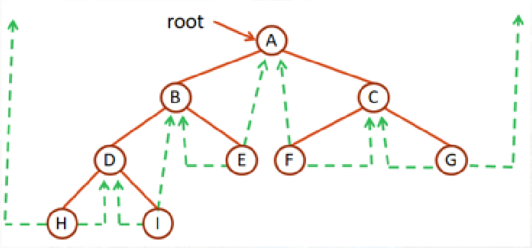


Threading Rules

- if `ptr->leftChild` is NULL, then `ptr->leftChild` = inorder predecessor (中序前行者) of `ptr`.
- if `ptr->rightChild` is NULL, then `ptr->rightChild` = inorder successor (中序後續者) of `ptr`.

To distinguish between normal pointers and threads

- Two additional fields of the node structure: left-thread, right-thread.

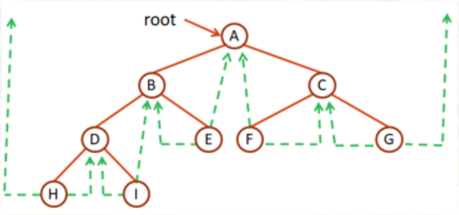
```
typedef struct threadedTree *threadedPointer;

typedef struct threadedTree {
    bool leftThread;
    threadedPointer leftChild;
    char data;
    threadedPointer rightChild;
    bool rightThread;
};
```

leftThread	leftChild	data	rightChild	rightThread

Rules of the Threading Fields

- If `ptr->leftThread == true`, `ptr->leftChild` contains a thread; Otherwise, the node contains a pointer to the left child.
- If `ptr->rightThread == true`, `ptr->righChild` contains a thread; Otherwise, the node contains a pointer to the right child.



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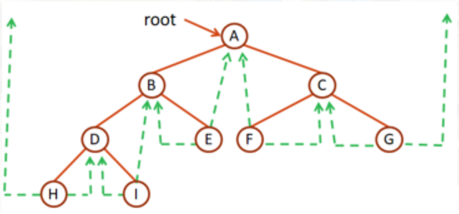
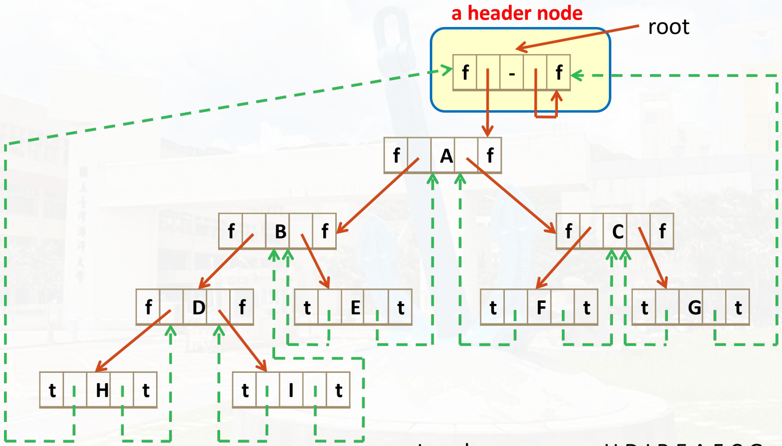


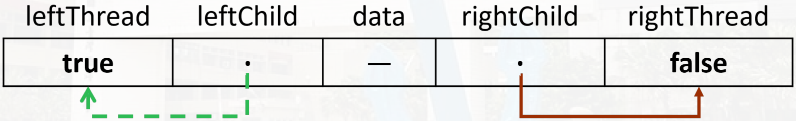
- Two dangling threads at node *H* and *G*.
  $\Rightarrow$ Use a header node to collect them!

- The original tree becomes the left subtree of the head node.



Inorder sequence: H D I B E A F C G

Representing an Empty Binary Tree



Finding the Inorder Successor of Node

```
threadedPointer insucc(threadedPointer tree) {
/* find the inorder sucessor of tree in a threaded
   binary tree */
    threadedPointer temp;
    temp = tree->rightChild;
    if (!tree->rightThread) // rightChild exists!
        while (!temp->leftThread)
            temp = temp->leftChild;
    return temp;
}
```

To perform an inorder traversal, we can simply make repeated calls to insucc!

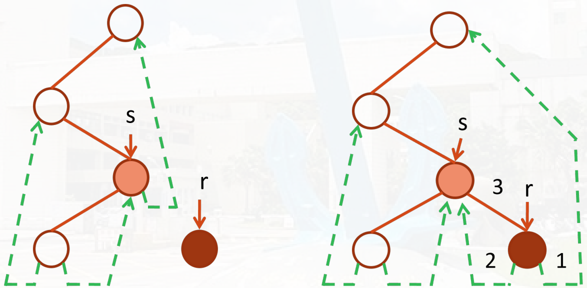
Inorder Traversal of a Threaded Binary Tree

```
void traverseInorder(threadedPointer tree) {
/* traverse the threaded binary tree inorder */
    threadedPointer temp = tree;
    while (1) {
        temp = insucc(temp);
        if (temp == tree)
            break;
        printf("%3c", temp->data);
    }
}
```

- **Note:** `temp == tree` happens when the last node is visited (then the successor becomes the header node).

Inserting *r* as the rightChild of a node *s*

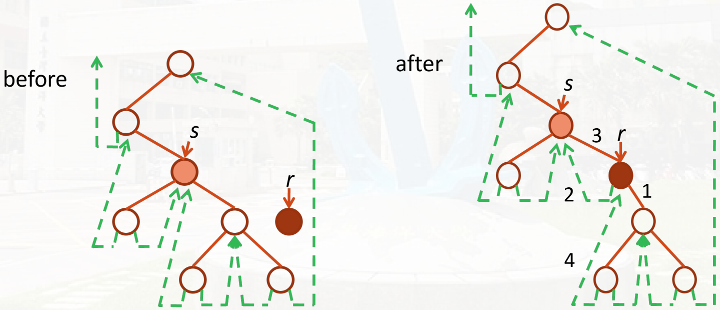
- Case I: `s->rightThread == true` (*s* has an empty subtree)



before after

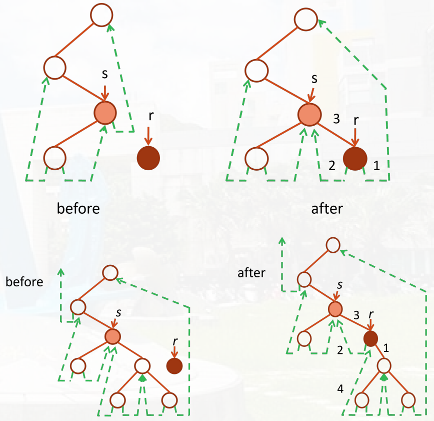
Inserting *r* as the rightChild of a node *s*

- Case II: `s->rightThread == false`
  (the right subtree of *s* is not empty)



The Code for the Insertion

```
void insertRight (threadedPointer s,
                  threadedPointer r) {
/* insert r as the right child of s */
    threadedPointer temp;
    r->rightChild = s->rightChild;
    r->rightThread = s->rightThread; // (*)
    r->leftChild = s;
    r->leftThread = true;
    s->rightChild = r;
    s->rightThread = false;
    if (!r->rightThread){ // step 4 (*)
        temp = insucc(r);
        temp->leftChild = r;
    }
}
```



Discussions