05-D

二叉树

二叉树实现

Anyone who loves his father or mother more than me is not worthy of me; anyone who loves his son or daughter more than me is not worthy of me.

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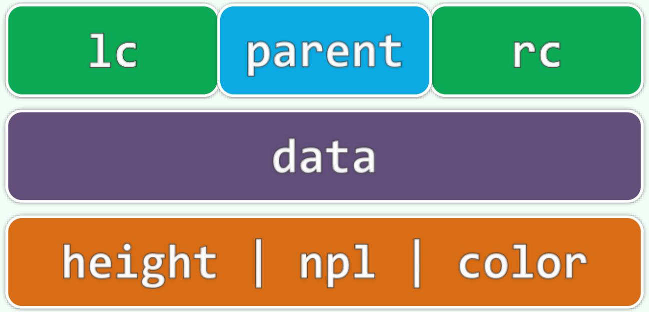
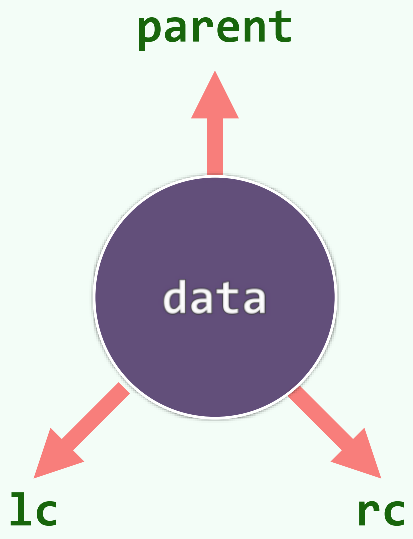
BinNode模板类

```
❖ template <typename> using BinNodePosi = BinNode<T>*; //节点位置
❖ template <typename T> struct BinNode {
      BinNodePosi<T> parent, lc, rc; //父亲、孩子
      T data; int height; int size(); //高度、子树规模
      BinNodePosi<T> insertAsLC( T const & ); //作为左孩子插入新节点
      BinNodePosi<T> insertAsRC( T const & ); //作为右孩子插入新节点
      BinNodePosi<T> succ(); //（中序遍历意义下）当前节点的直接后继
      template <typename VST> void travLevel( VST & ); //子树层次遍历
      template <typename VST> void travPre( VST & ); //子树先序遍历
      template <typename VST> void travIn( VST & ); //子树中序遍历
      template <typename VST> void travPost( VST & ); //子树后序遍历
  };
```



lc	parent	rc
data		
height | npl | color		

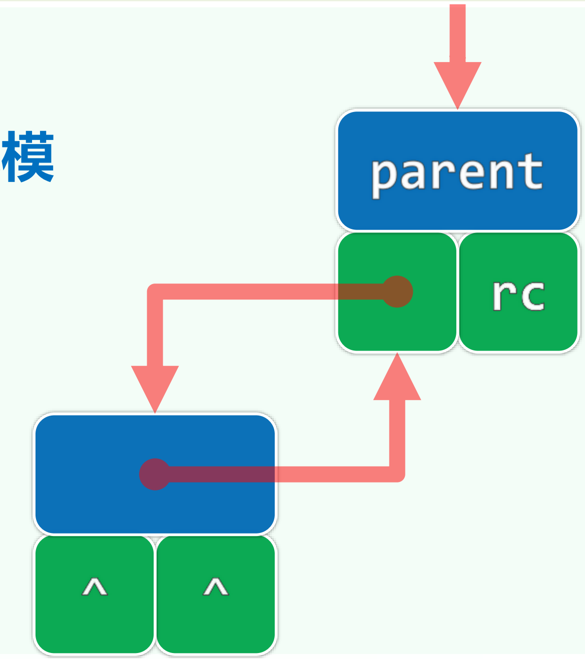


BinNode接口实现

```
❖ template <typename T> BinNodePosi<T> BinNode<T>::insertAsLC( T const & e )
     { return lc = new BinNode( e, this ); }
```

```
❖ template <typename T> BinNodePosi<T> BinNode<T>::insertAsRC( T const & e )
     { return rc = new BinNode( e, this ); }
```

```
❖ template <typename T>
  int BinNode<T>::size() { //后代总数，亦即以其为根的子树的规模
     int s = 1; //计入本身
     if (lc) s += lc->size(); //递归计入左子树规模
     if (rc) s += rc->size(); //递归计入右子树规模
     return s;
  } //O( n = |size| )
```



BinTree模板类

```
template <typename T> class BinTree {
protected: int _size; //规模
           BinNodePosi<T> _root; //根节点
           virtual int updateHeight( BinNodePosi<T> x ); //更新节点x的高度
           void updateHeightAbove( BinNodePosi<T> x ); //更新x及祖先的高度
public:    int size() const { return _size; } //规模
           bool empty() const { return !_root; } //判空
           BinNodePosi<T> root() const { return _root; } //树根
           /* ... 子树接入、删除和分离接口；遍历接口 ... */
}
```

高度更新

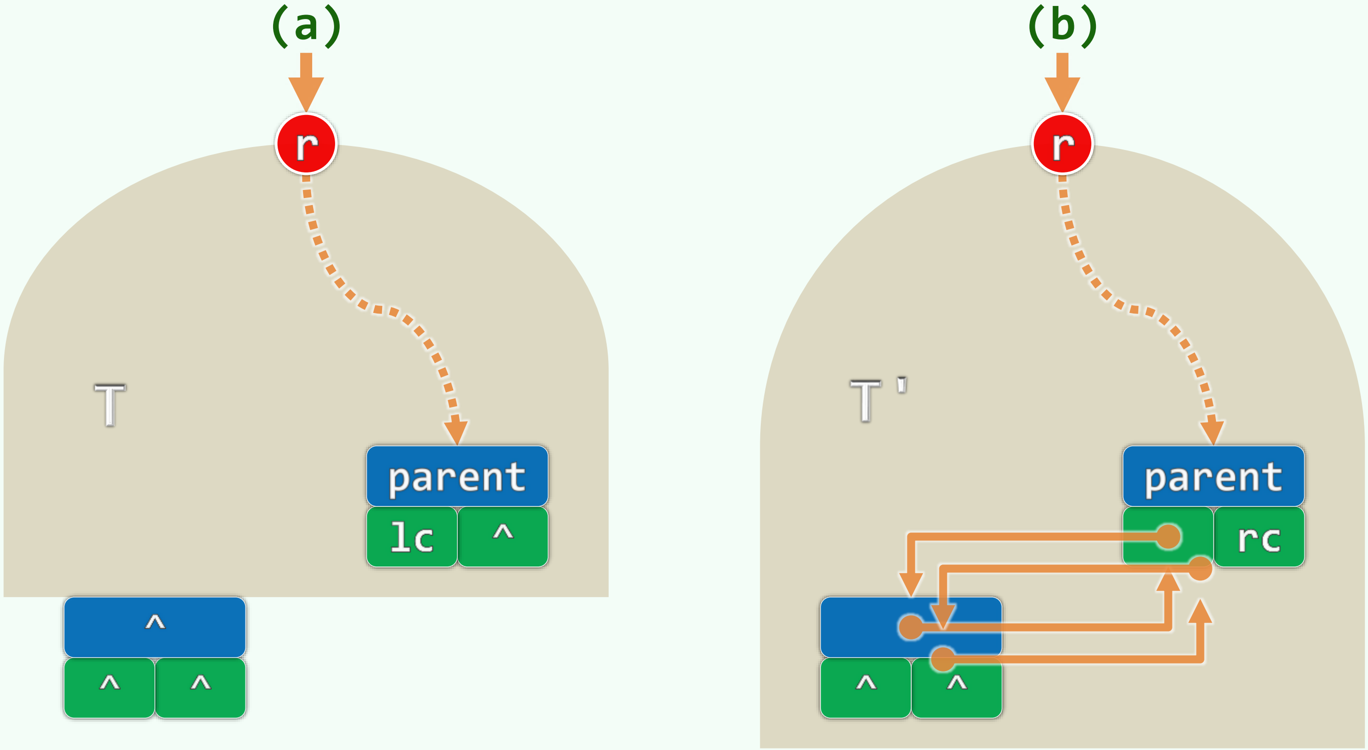
```
#define stature(p) ( (p) ? (p)->height : -1 ) //节点高度——空树 ~ -1
```

```
template <typename T> //更新节点x高度，具体规则因树不同而异
int BinTree<T>::updateHeight( BinNodePosi<T> x ) //此处采用常规二叉树规则，𝒪(1)
   { return  x->height  =  1 + max( stature( x->lc ), stature( x->rc ) ); }
```

```
template <typename T> //更新v及其历代祖先的高度
void BinTree<T>::updateHeightAbove( BinNodePosi<T> x ) //𝒪( n = depth(x) )
   { while (x) { updateHeight(x); x = x->parent; } } //可优化
```

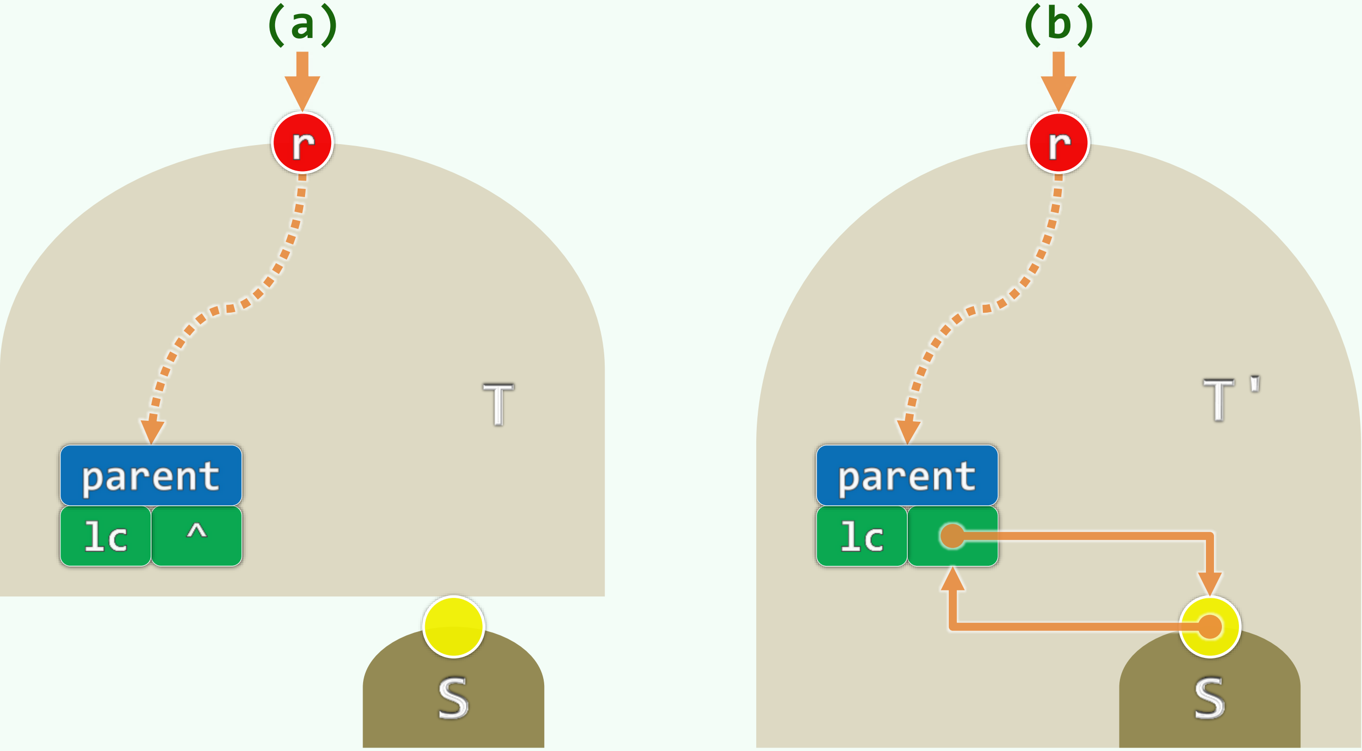
节点插入

```
BinNodePosi<T> BinTree<T>::insert( BinNodePosi<T> x, T const & e ); //作为右孩子

BinNodePosi<T> BinTree<T>::insert( T const & e, BinNodePosi<T> x ) {//作为左孩子
   _size++;
   x->insertAsLC( e );
   updateHeightAbove( x );
   return x->rc;
}
```



子树接入

```
BinNodePosi<T> BinTree<T>::attach( BinTree<T>* &S, BinNodePosi<T> x ); //接入左子树

BinNodePosi<T> BinTree<T>::attach( BinNodePosi<T> x, BinTree<T>* &S ) {//接入右子树

   if ( x->rc = S->_root )

      x->rc->parent = x;

   _size += S->_size;

   updateHeightAbove(x);

   S->_root = NULL; S->_size = 0;

   release(S); S = NULL;

   return x;

}
```



子树删除

```
❖ template <typename T> int BinTree<T>::remove( BinNodePosi<T> x ) {
     FromParentTo( * x ) = NULL;
     updateHeightAbove( x->parent ); //更新祖先高度（其余节点亦不变）
     int n = removeAt(x); _size -= n; return n;
  }
```

```
❖ template <typename T> static int removeAt( BinNodePosi<T> x ) {
     if ( ! x ) return 0;
     int n = 1 + removeAt( x->lc ) + removeAt( x->rc );
     release(x->data); release(x); return n;
  }
```

子树分离

```
template <typename T> BinTree<T>* BinTree<T>::secede( BinNodePosi<T> x ) {
   FromParentTo( * x ) = NULL;
   updateHeightAbove( x->parent );
// 以上与BinTree<T>::remove()一致；以下还需对分离出来的子树重新封装
   BinTree<T> * S = new BinTree<T>; //创建空树
   S->_root = x; x->parent = NULL; //新树以x为根
   S->_size = x->size(); _size -= S->_size; //更新规模
   return S; //返回封装后的子树
}
```