5.二叉树

（d）二叉树实现

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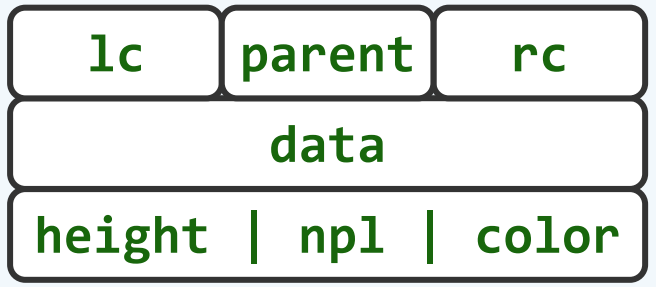
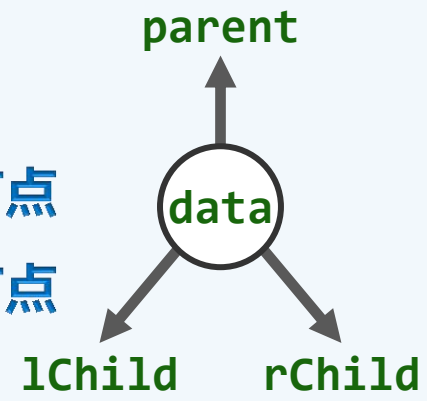
BinNode模板类




```
❖ #define BinNodePosi(T) 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
};
```

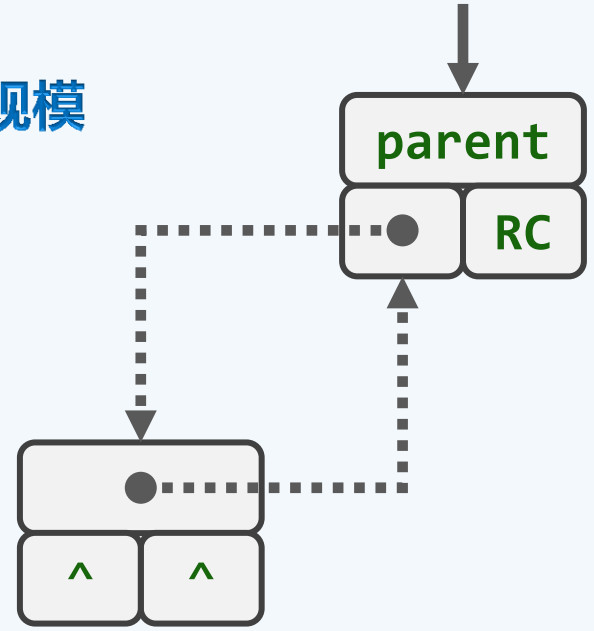


BinNode接口实现

```
❖ 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

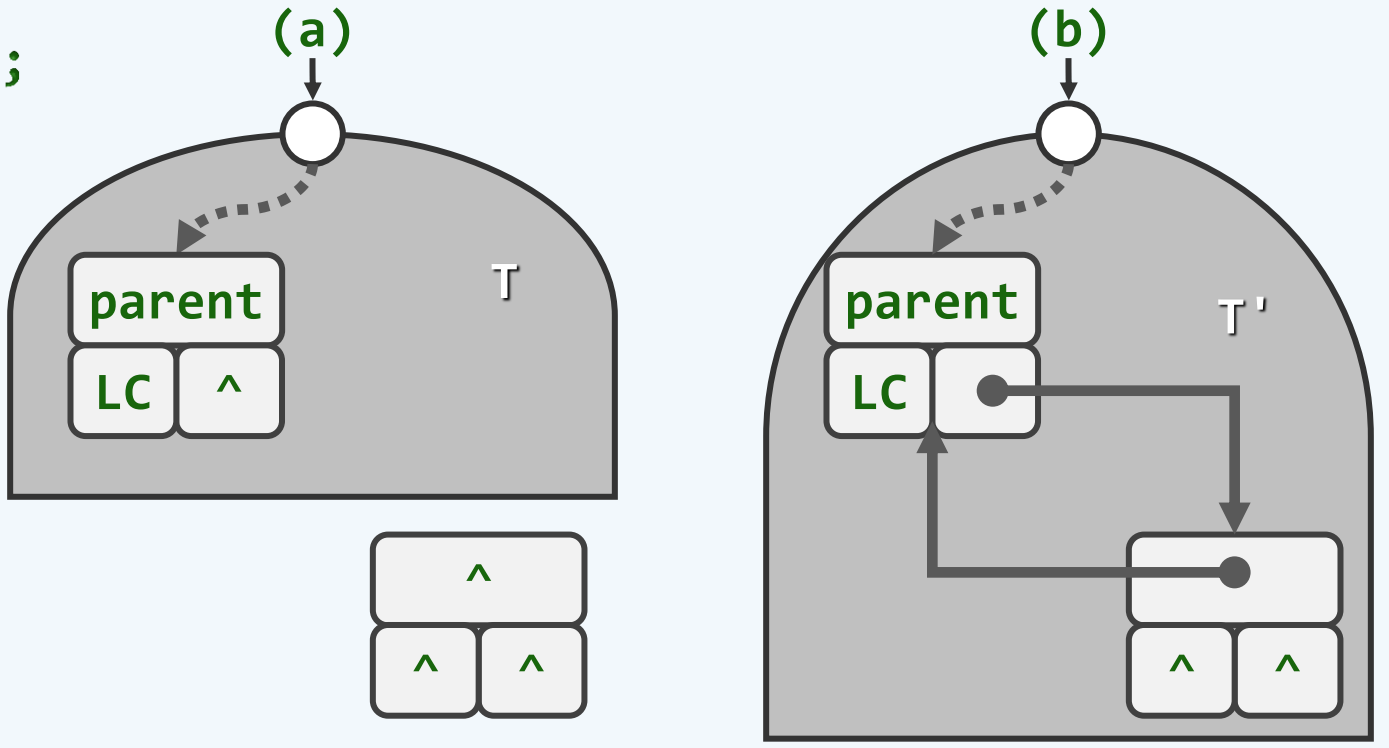
❖ `#define stature(p) ( (p) ? (p)->height : -1 )` //节点高度——约定空树高度为-1

❖
```
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 ) {
   return x->height = 1 +
      max( stature( x->lc ), stature( x->rc ) );
} //此处采用常规二叉树规则，O(1)
```

❖
```
template <typename T> //更新v及其历代祖先的高度
void BinTree<T>::updateHeightAbove( BinNodePosi(T) x ) {
   while (x) //可优化：一旦高度未变，即可终止
      { updateHeight(x); x = x->parent; }
} //O( n = depth(x) )
```

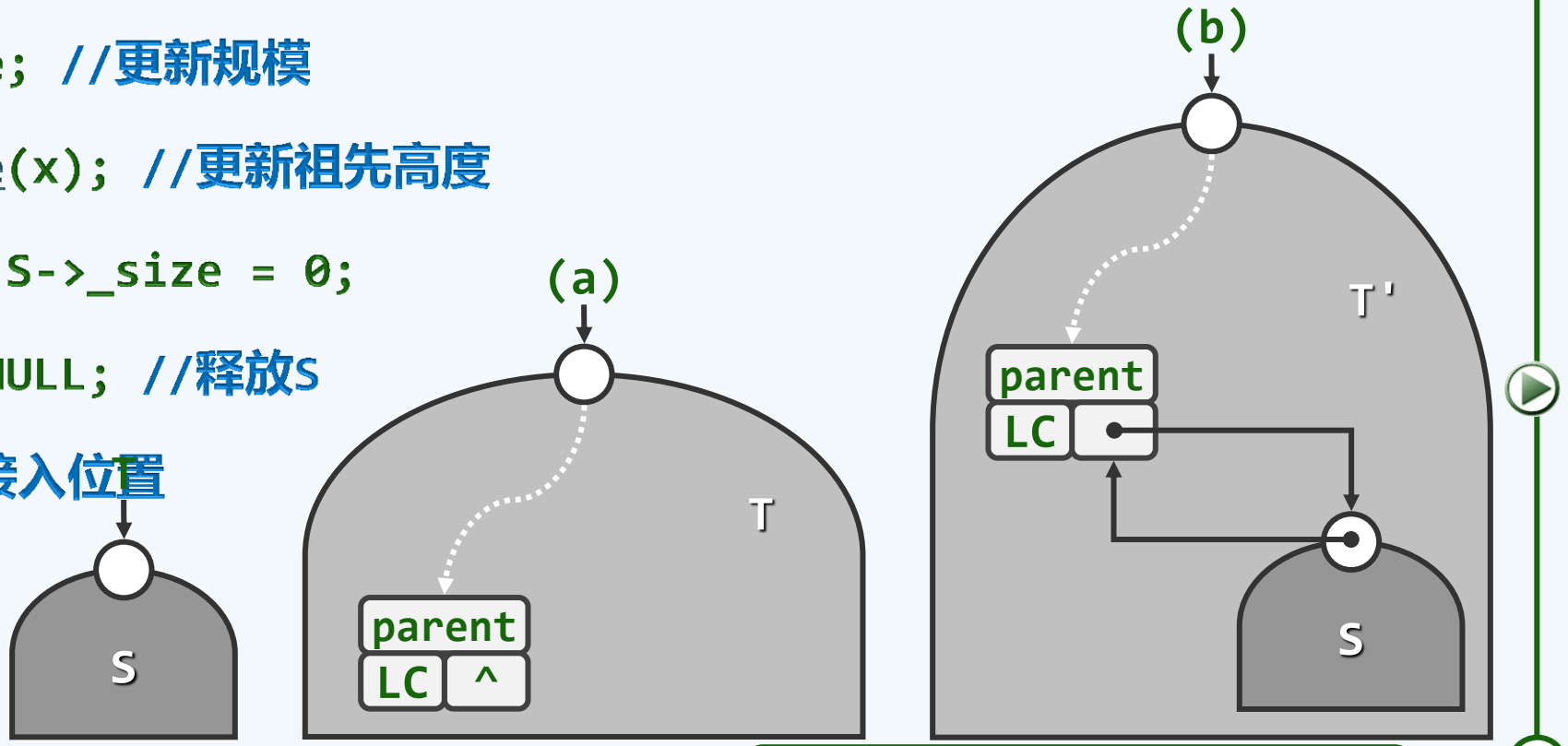
节点插入

```
template <typename T> BinNodePosi(T)
BinTree<T>::insertAsRC( BinNodePosi(T) x, T const & e ) { //insertAsLC()对称
   _size++; x->insertAsRC(e); //x祖先的高度可能增加，其余节点必然不变
   updateHeightAbove(x);
   return x->rc;
}
```



子树接入

```
template <typename T>
BinNodePosi(T) BinTree<T>::attachAsRC( BinNodePosi(T) x, BinTree<T>* & S ) {
    if ( x->rc = S->_root ) x->rc->parent = x; //接入
    _size += S->_size; //更新规模
    updateHeightAbove(x); //更新祖先高度
    S->_root = NULL; S->_size = 0;
    release(S); S = NULL; //释放S
    return x; //返回接入位置
} //attachAsLC()对称
```



子树删除

```
❖template <typename T>
  int BinTree<T>::remove( BinNodePosi(T) x ) { //子树接入的逆过程
     FromParentTo( * x ) = NULL; //切断来自父节点的指针
     updateHeightAbove( x->parent ); //更新祖先高度（其余节点亦不变）
     int n = removeAt(x); _size -= n; //递归删除x及其后代，更新规模
     return n; //返回被删除节点总数
  }

❖template <typename T> static int removeAt( BinNodePosi(T) x ) {
     if ( ! x ) return 0; //终止于空子树，否则左、右递归
     int n = 1 + removeAt( x->lc ) + removeAt( x->rc );
     release(x->data); release(x); return n; //释放被摘除节点，并返回被删除节点总数
  }
```

子树分离

- 过程与以上的子树删除操作BinTree<T>::remove()基本一致
- 不同之处在于，需对分离出来的子树重新封装，并返回给上层调用者
-

```
template <typename T>
BinTree<T>* BinTree<T>::secede( BinNodePosi(T) x ) {
    FromParentTo( * x ) = NULL; //切断来自父节点的指针
    updateHeightAbove( x->parent ); //更新原树中所有祖先的高度
// 以下对分离出的子树做封装
    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
}
```