2018. 3. 9 금 – 12 회차

과정 : TI, DSP, Xilinx Znq FPGA, MCU 기반의 프로그래밍 전문가 과정

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자료구조_5

Red – Black tree

// 루트노드는 항상 검정
// 잎사귀노드 어디를 가던지 거치는 검정색의 개수가 서로 모두 같다.
// 빨간색이 두개가 연달아 오면 회전 or 색이 바뀐다.(level 과는 관련없음, rb tree 에서는 level 자체가 존재 x)
// 현재 기준점에서 부모노드와 삼촌의 색상이 같으면 색상만 변경함. 할아버지가 빨강색이 되고 자식들은 검정색이 된다.
// 3 번규칙을 만족하는데, 4 번이 만족되지 않으면 회전

//특징 양극단의 길이는 최대 2 배까지 가능

//RB 트리를 사용하는 이유 : AVL 트리보다 검색속도는 느리지만, 입,출력속도가 빨라서 사용(rotation 이 빈번하게 일어나지 않고, 어느정도 트리의 모양을 유지하여 검색속도도 빠른 편)

```
#include <time.h>
#include <stdio.h>
#include <stdlib.h>
#include <stdbool.h>

#define	BLACK	0
#define	RED	1

typedef struct __rb_node
{
	int data;
```

```
	int color;

	struct __rb_node *left;
	struct __rb_node *right;
	struct __rb_node *parent;
} rb_node;

typedef struct __rb_tree
{
	struct __rb_node *root;
	struct __rb_node *nil;
} rb_tree;

bool is_dup(int *arr, int cur_idx)
{
	int i, tmp = arr[cur_idx];

	for(i = 0; i < cur_idx; i++)
		if(tmp == arr[i])
			return true;

	return false;
}

void init_rand_arr(int *arr, int size)
{
	int i;

	for(i = 0; i < size; i++)
	{
redo:
		//arr[i] = rand() % 15 + 1;
		arr[i] = rand() % 200 + 1;

		if(is_dup(arr, i))
		{
			printf("%d dup! redo rand()\n", arr[i]);
			goto redo;
		}
	}
}
```

```
void rb_left_rotate(rb_tree **tree, rb_node *x)
{
	rb_node *y;
	rb_node *nil = (*tree)->nil;

	y = x->right;
	x->right = y->left;

	if(y->left != nil)
		y->left->parent = x;

	y->parent = x->parent;

	if(x == x->parent->left)
		x->parent->left = y;
	else
		x->parent->right = y;

	y->left = x;
	x->parent = y;
}

void rb_right_rotate(rb_tree **tree, rb_node *y)
{
	rb_node *x;
	rb_node *nil = (*tree)->nil;

	x = y->left;
	y->left = x->right;

	if(nil != x->right)
		x->right->parent = y;

	x->parent = y->parent;

	if(y->parent->left == y)
		y->parent->left = x;
	else
		y->parent->right = x;

	x->right = y;
	y->parent = x;
```

```
}

void rb_tree_ins_helper(rb_tree **tree, rb_node *z)  //부모랑 자식이랑 연결해 주는 역할
{
	rb_node *x;
	rb_node *y;
	rb_node *nil = (*tree)->nil;

	z->left = z->right = nil;
	y = (*tree)->root;
	x = (*tree)->root->left;

	while(x != nil)			//왼쪽에 넣을지 오른쪽에 넣을지
	{
		y = x;

		if(x->data > z->data)
			x = x->left;
		else
			x = x->right;
	}

	z->parent = y;

	if(((*tree)->root == y) || (y->data > z->data))
		y->left = z;
	else
		y->right = z;
}

rb_node *rb_tree_ins(rb_tree **tree, int data)
{
	rb_node *x;
	rb_node *y;
	rb_node *tmp;

	x = (rb_node *)malloc(sizeof(rb_node));
	x->data = data;

	rb_tree_ins_helper(tree, x);
```

```
tmp = x;
x->color = RED;

while(x->parent->color)    //빨간색 다음 빨간색 -> 회전
{
	if(x->parent == x->parent->parent->left)
	{
		y = x->parent->parent->right;

		if(y->color)
		{
			x->parent->color = BLACK;
			y->color = BLACK;
			x->parent->parent->color = RED;
			x = x->parent->parent;
		}
		else
		{
			if(x->parent->right == x)
			{
				x = x->parent;
				rb_left_rotate(tree, x);
			}

			x->parent->color = BLACK;
			x->parent->parent->color = RED;

			rb_right_rotate(tree, x->parent->parent);
		}
	}
	else
	{
		y = x->parent->parent->left;

		if(y->color)
		{
			x->parent->color = BLACK;
			y->color = BLACK;
			x->parent->parent->color = RED;
			x = x->parent->parent;
```

```
                }
                else
                {
                        if(x->parent->left == x)
                        {
                                x = x->parent;
                                rb_right_rotate(tree, x);
                        }

                        x->parent->color = BLACK;
                        x->parent->parent->color = RED;

                        rb_left_rotate(tree, x->parent->parent);
                }
        }
    }

    (*tree)->root->left->color = BLACK;

    return tmp;
}

rb_tree *rb_tree_create(void)
{
    rb_tree *rbt;
    rb_node *tmp;

    rbt = (rb_tree *)malloc(sizeof(rb_tree));

    tmp = rbt->nil = (rb_node *)malloc(sizeof(rb_node));
    tmp->parent = tmp->left = tmp->right = tmp;
    tmp->color = BLACK;
    tmp->data = 0;

    tmp = rbt->root = (rb_node *)malloc(sizeof(rb_node));
    tmp->parent = tmp->left = tmp->right = rbt->nil;
    tmp->color = BLACK;
    tmp->data = 0;

    return rbt;
}
```

```
void rb_tree_preorder_print(rb_tree *tree, rb_node *x)
{
	rb_node *nil = tree->nil;
	rb_node *root = tree->root;

	if(x != tree->nil)
	{
		printf("data = %4i, ", x->data);

		if(x->left == nil)
			printf("left = NULL, ");
		else
			printf("left = %4i, ", x->left->data);

		if(x->right == nil)
			printf("right = NULL, ");
		else
			printf("right = %4i, ", x->right->data);

		printf("color = %4i\n", x->color);

		rb_tree_preorder_print(tree, x->left);
		rb_tree_preorder_print(tree, x->right);
	}
}

void rb_tree_print(rb_tree *tree)
{
	rb_tree_preorder_print(tree, tree->root->left);
}

int data_test(int n1, int n2)
{
	if(n1 > n2)
		return 1;
	else if(n1 < n2)
		return -1;
	else
		return 0;
}

rb_node *rb_tree_find(rb_tree *tree, int data)
```

```
{
	int tmp;

	rb_node *x = tree->root->left;
	rb_node *nil = tree->nil;

	if(x == nil)
		return 0;

	tmp = data_test(x->data, data);

	while(tmp != 0)
	{
		if(x->data > data)
			x = x->left;
		else
			x = x->right;

		if(x == nil)
			return 0;

		tmp = data_test(x->data, data);
	}

	return x;
}

rb_node *rb_tree_successor(rb_tree *tree, rb_node *x)
{
	rb_node *y;
	rb_node *nil = tree->nil;
	rb_node *root = tree->root;

	if(nil != (y = x->right))
	{
		while(y->left != nil)
			y = y->left;

		return y;
	}
	else
	{
```

```
            y = x->parent;

            while(y->right == x)
            {
                x = y;
                y = y->parent;
            }

            if(y == root)
                return nil;

            return y;
        }
}

void rb_tree_del_fixup(rb_tree *tree, rb_node *x)
{
        rb_node *root = tree->root->left;
        rb_node *w;

        while((!x->color) && (root != x))
        {
            if(x->parent->left == x)
            {
                w = x->parent->right;

                if(w->color)
                {
                    w->color = BLACK;
                    x->parent->color = RED;
                    rb_left_rotate(&tree, x->parent);
                    w = x->parent->right;
                }

                if((!w->right->color) && (!w->left->color))
                {
                    w->color = RED;
                    x = x->parent;
                }
                else
                {
                    if(!w->right->color)
```

```
                {
                        w->left->color = BLACK;
                        w->color = RED;
                        rb_right_rotate(&tree, w);
                        w = x->parent->right;
                }

                w->color = x->parent->color;
                x->parent->color = BLACK;
                w->right->color = BLACK;
                rb_right_rotate(&tree, x->parent);
                x = root;
        }
}
else
{
        w = x->parent->left;

        if(w->color)
        {
                w->color = BLACK;
                x->parent->color = 1;
                rb_right_rotate(&tree, x->parent);
                w = x->parent->left;
        }

        if((!w->right->color) && (!w->left->color))
        {
                w->color = RED;
                x = x->parent;
        }
        else
        {
                if((!w->right->color) && (!w->left->color))
                {
                        w->right->color = BLACK;
                        w->color = RED;
                        rb_left_rotate(&tree, w);
                        w = x->parent->left;
                }

                w->color = x->parent->color;
```

```
                        x->parent->color = BLACK;
                        w->left->color = BLACK;
                        rb_right_rotate(&tree, x->parent);
                        x = root;
                }
        }
    }

    x->color = BLACK;
}

void rb_tree_del(rb_tree *tree, rb_node *z)
{
    rb_node *y;
    rb_node *x;
    rb_node *nil = tree->nil;
    rb_node *root = tree->root;

    y = ((z->left == nil) || (z->right == nil)) ?
            z : rb_tree_successor(tree, z);
    x = (y->left == nil) ? y->right : y->left;

    if(root == (x->parent = y->parent))
        root->left = x;
    else
    {
        if(y == y->parent->left)
            y->parent->left = x;
        else
            y->parent->right = x;
    }

    if(y != z)
    {
        if(!(y->color))
            rb_tree_del_fixup(tree, x);

        y->left = z->left;
        y->right = z->right;
        y->parent = z->parent;
        y->color = z->color;
        z->left->parent = z->right->parent = y;
```

```
            if(z->parent->left == z)
                z->parent->left = y;
            else
                z->parent->right = y;

            free(z);
        }
        else
        {
            if(!(y->color))
                rb_tree_del_fixup(tree, x);

            free(y);
        }
}

int main(void)
{
        int i, size;
        int data[21] = {0};

        rb_tree *rbt = NULL;
        rb_node *find = NULL;

        srand(time(NULL));

        size = sizeof(data) / sizeof(int) - 1;

        init_rand_arr(data, size);

        rbt = rb_tree_create();

        for(i = 0; i < size; i++)
            rb_tree_ins(&rbt, data[i]);

        rb_tree_print(rbt);

        find = rb_tree_find(rbt, data[5]);

        rb_tree_del(rbt, find);
        printf("\nAfter Delete\n");
```

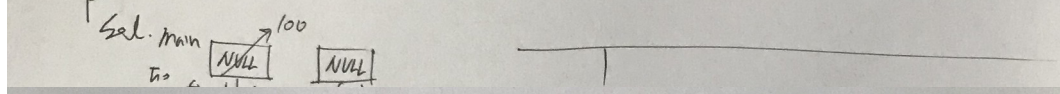
```
        rb_tree_print(rbt);

        return 0;
}
```

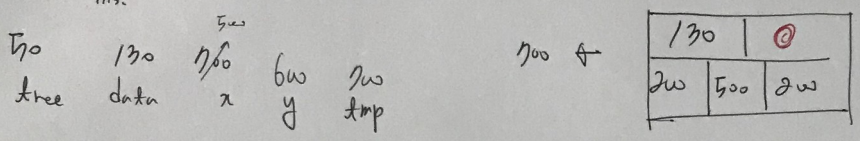
Sol.

<12회차>

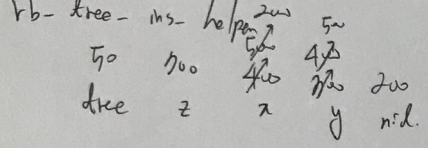
red-black tree.



rb_tree_ins.



rb_tree_ins_help



rb_left_rotate