QuickSort on Doubly Linked List

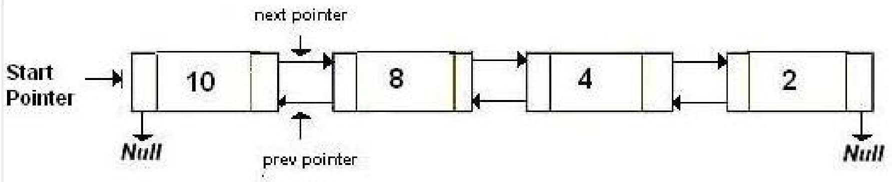
Following is a typical recursive implementation of QuickSort for arrays. The implementation uses last element as pivot.

```
/* A typical recursive implementation of Quicksort for array*/

/* This function takes last element as pivot, places the pivot element at its
   correct position in sorted array, and places all smaller (smaller than
   pivot) to left of pivot and all greater elements to right of pivot */
int partition (int arr[], int l, int h)
{
    int x = arr[h];
    int i = (l - 1);

    for (int j = l; j <= h- 1; j++)
    {
        if (arr[j] <= x)
        {
            i++;
            swap (&arr[i], &arr[j]);
        }
    }
    swap (&arr[i + 1], &arr[h]);
    return (i + 1);
}

/* A[] --> Array to be sorted, l  --> Starting index, h  --> Ending index */
void quickSort(int A[], int l, int h)
{
    if (l < h)
    {
        int p = partition(A, l, h); /* Partitioning index */
        quickSort(A, l, p - 1);
        quickSort(A, p + 1, h);
    }
}
```

Run on IDE

Can we use same algorithm for Linked List?

Following is C++ implementation for doubly linked list. The idea is simple, we first find out pointer to last node. Once we have pointer to last node, we can recursively sort the linked list using pointers to first and last nodes of linked list, similar to the above recursive function where we pass indexes of first and last array elements. The partition function for linked list is also similar to partition for arrays. Instead of returning index of the pivot element, it returns pointer to the pivot element. In the following implementation, quickSort() is just a wrapper function, the main recursive function is _quickSort() which is similar to quickSort() for array implementation.



```
// A C++ program to sort a linked list using Quicksort
#include <iostream>
#include <stdio.h>
using namespace std;

/* a node of the doubly linked list */
struct node
{
    int data;
    struct node *next;
    struct node *prev;
};

/* A utility function to swap two elements */
void swap ( int* a, int* b )
{   int t = *a;      *a = *b;       *b = t;   }

// A utility function to find last node of linked list
struct node *lastNode(node *root)
{
    while (root && root->next)
        root = root->next;
    return root;
}

/* Considers last element as pivot, places the pivot element at its
   correct position in sorted array, and places all smaller (smaller than
   pivot) to left of pivot and all greater elements to right of pivot */
node* partition(node *l, node *h)
{
    // set pivot as h element
    int x  = h->data;

    // similar to i = l-1 for array implementation
    node *i = l->prev;

    // Similar to "for (int j = l; j <= h- 1; j++)"
    for (node *j = l; j != h; j = j->next)
    {
        if (j->data <= x)
        {
            // Similar to i++ for array
            i = (i == NULL)? l : i->next;

            swap(&(i->data), &(j->data));
        }
    }
    i = (i == NULL)? l : i->next; // Similar to i++
    swap(&(i->data), &(h->data));
    return i;
}

/* A recursive implementation of quicksort for linked list */
```

```
void _quickSort(struct node* l, struct node *h)
{
    if (h != NULL && l != h && l != h->next)
    {
        struct node *p = partition(l, h);
        _quickSort(l, p->prev);
        _quickSort(p->next, h);
    }
}

// The main function to sort a linked list. It mainly calls _quickSort()
void quickSort(struct node *head)
{
    // Find last node
    struct node *h = lastNode(head);

    // Call the recursive QuickSort
    _quickSort(head, h);
}

// A utility function to print contents of arr
void printList(struct node *head)
{
    while (head)
    {
        cout << head->data << "  ";
        head = head->next;
    }
    cout << endl;
}

/* Function to insert a node at the begiging of the Doubly Linked List */
void push(struct node** head_ref, int new_data)
{
    struct node* new_node = new node;     /* allocate node */
    new_node->data  = new_data;

    /* since we are adding at the begining, prev is always NULL */
    new_node->prev = NULL;

    /* link the old list off the new node */
    new_node->next = (*head_ref);

    /* change prev of head node to new node */
    if ((*head_ref) !=  NULL)  (*head_ref)->prev = new_node ;

    /* move the head to point to the new node */
    (*head_ref)    = new_node;
}

/* Driver program to test above function */
int main()
{
    struct node *a = NULL;
    push(&a, 5);
    push(&a, 20);
    push(&a, 4);
    push(&a, 3);
    push(&a, 30);

    cout << "Linked List before sorting \n";
    printList(a);

    quickSort(a);
    cout << "Linked List after sorting \n";
    printList(a);

    return 0;
}
```

Run on IDE

Output :

```
Linked List before sorting
30  3  4  20  5
Linked List after sorting
3  4  5  20  30
```

Time Complexity: Time complexity of the above implementation is same as time complexity of QuickSort() for arrays. It takes O(n^2) time in worst case and O(nLogn) in average and best cases. The worst case occurs when the linked list is already sorted.

Can we implement random quick sort for linked list?
Quicksort can be implemented for Linked List only when we can pick a fixed point as pivot (like last element in above implementation). Random QuickSort cannot be efficiently implemented for Linked Lists by picking random pivot.

Exercise:
The above implementation is for doubly linked list. Modify it for singly linked list. Note that we don't have prev pointer in singly linked list.
Refer QuickSort on Singly Linked List for solution.

Please write comments if you find anything incorrect, or you want to share more information about the topic discussed above

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TulsiRam • 4 months ago

if (h != NULL && l != h && l != NULL){
}

Why the above condition is not right?? Please help I am stuck

• Reply • Share ›

Akilan Arasu • 4 months ago

Easy code for quicksort for singly linked list in C:
http://ideone.com/PLEigd

Data is being swapped, not pointers.

• Reply • Share ›

abhishek agrawal • 5 months ago

if (h != NULL && l != h && l != h->next) here what is the use of (l != h->next) condition

1 • Reply • Share ›

Hitesh Saini • 6 months ago

more easier implementation

see the code here

http://ideone.com/pYz4EN

if any doubt or bug is found please reply..:)

• Reply • Share ›

Pallavi Singh • 8 months ago

In one of the posts that i read here, it was said that QuickSort is not the sort for LinkedList as it performs poorly rather merge sort should be used, please clear the confusion someone?

2 • Reply • Share ›

GeeksforGeeks Mod Pallavi Singh • 8 months ago

Pallavi,

One possible reason could be caching. QuickSort has good locality of reference when used for arrays, that is one of the main reasons quicksort is preferred over mergesort for arrays.

In linked lists, locality of reference is not possible as nodes are at different locations.

Also, merge sort for arrays requires auxiliary array to merge while QuickSort does sorting in-place. In case of linked lists, merge() operation of mergesort() doesn't require an auxiliary array.

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Prince Bharti GeeksforGeeks • 5 months ago

but how does quick sort in place ? i mean it takes o(log n) space for function call stack in best case and o(n) in worst case .. please clarify me ?

• Reply • Share ›

Pallavi Singh GeeksforGeeks • 8 months ago

what do you mean when you say "locality of reference"?

• Reply • Share ›

GOPI GOPINATH ↪ Pallavi Singh • 8 months ago

Locality of reference is a computer science concept, in simple words, Instead of picking up a single element, we ll pick few elements near to that element because they have maximum possibility to be picked in near future.

1 • Reply • Share ›

Pallavi Singh ↪ GOPI GOPINATH • 8 months ago

Thanks @Gopi Gopinath :)

• Reply • Share ›

Goku • 9 months ago

@geeksforgeeks here is the implementation of merge sort for doubly linked list.Please publish this :)
http://ideone.com/LSnLwA

• Reply • Share ›

Rauf • a year ago

Please Help me...I am doing quick sort ....But it does not working fine....i have to enter sorting option again and again to sort data

http://ideone.com/VXxAuI

• Reply • Share ›

Kerem Sahin • a year ago

Implementation by changing links (not data)

http://ideone.com/qQIvb8

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coderr ↪ Kerem Sahin • 5 months ago

Can you explain the logic you are using in your code?

• Reply • Share ›

ajayv • a year ago

@GeeksforGeeks
In the function _quicksort
the condition states that

if (h != NULL && l != h && l != h->next)

shouldn't it be
h!=l->next. and its working also and seems to be logical.

that case will never arises bcoz before that they will be cancelled out by the condition (l != h). please reply ASAP.

• Reply • Share ›

Klaus • 2 years ago

if (h != NULL && l != h && l != h->next)
{
struct node *p = partition(l, h);
_quickSort(l, p->prev);
_quickSort(p->next, h);
}
Why we are doing l!=h->next comparison

5 • Reply • Share ›

amateur Klaus • a year ago

its similar to 'if(l>h)' , which is a condition we don't want.

• Reply • Share ›

MK Klaus • 2 years ago

Did you get answer for this?

• Reply • Share ›

brahma • 2 years ago

hear is my implementation swapping nodes instead of data... i used same logic of single linked list
http://ideone.com/uXGl81

@geeks can you tell me is there any decrease in run time by implementing in double linked list

• Reply • Share ›

LinkedListFML • 2 years ago

Can someone give an implementation based on SWAPPING POINTERS instead of DATA. I tried a lot but was unsuccessful :(

• Reply • Share ›

FrakIt LinkedListFML • a year ago

```
#include<stdlib.h>

#include<stdio.h>

struct node

{
```

int data;

struct node *next;

struct node *prev;

};

void push(struct node **head, int val)

{

struct node *temp = (node*)malloc(sizeof(node));

see more

• Reply • Share ›

theCuriosityEnthusiast • 2 years ago

I'm new to this so can someone explain why randomized Quicksort cannot be efficiently implemented in a LL??

• Reply • Share ›

RK → theCuriosityEnthusiast • a year ago

random access is not possible in LL

• Reply • Share ›

madan raj • 2 years ago

l!=h->next case works
when there are less than 2 elements in sublists
and when pivot pointer is the same as end element

case try for 5 and 8

p will be pointing to 8

quicksort (5,5) //avoided l==h
and
quicksort(null,8) in this case l==h->next so avoided

3 • Reply • Share ›

Vishal • 2 years ago

what does this statement do ?

i = (i == NULL)? l : i->next;

• Reply • Share ›

edward • 2 years ago

why need swap (&arr[i + 1], &arr[h]); after loop?

• Reply • Share ›

cfh edward • 2 years ago

to put the pivot which is the last element, at its correct place.

• Reply • Share ›

LinuxWorld • 2 years ago

sorting the list using linked list

#include
#include

struct Node
{
int data ;
struct Node * next ;
};
typedef struct Node Node ;

Node *middle(Node *head)
{
Node *temp ;
if(head->next == NULL)
return head ;
else if(head->next->next == NULL)
return head ;

see more

1 • Reply • Share ›

Ronny • 3 years ago

@GeeksforGeeks
In the function _quicksort
the condition states that

if (h != NULL && l != h && l != h->next)

shouldn't it be
h!=l->next

since h pointer contains the last node
and the l pointer contains the first(head)node

so how can head be equal to last->next (Note : It is not a circular linked list)

• Reply • Share ›

nehamahajan Ronny • 2 years ago

h is last node of every sublist so h->next is possible and l!= h->next. It simply means that there must be more than two elements in sublists.

• Reply • Share ›

Ronny Ronny • 3 years ago

its not working if I remove that condition.
Can anyone explain in which case it is required.

• Reply • Share ›

numid • 3 years ago

One doubt,when and why does low becomes equal to high->next ?
Please comment

```
 void _quickSort(struct node* l, struct node *h)
{
    if (h != NULL && l != h && l != h->next)
    {
        struct node *p = partition(l, h);
        _quickSort(l, p->prev);
        _quickSort(p->next, h);
    }
}
```

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Pushkar numid • 2 years ago

Hey!.. Here in this code when recursive function "void _quickSort(struct node* l, struct node *h)" is narrowed down to two elements then the pivot element is either the first or second element .so..
case 1:when pivot element is the first element (p==l)
_quickSort(l, p->prev); set l as l and h as the previous element of p(or l) so the condition l!=h->next is violated()
case 1:when pivot element is the second element (p==h)
_quickSort(p->next,h); set h as h and l as the next element of p(or h) so the condition l!=h->next is violated
Hope it would help you!!!

1 • Reply • Share ›

ajayv Pushkar • a year ago

the cases which you are talking about they are special cases and they will violate the condition of (l != h).. . that means you are not getting the question which numid asked.

• Reply • Share ›

Akhil • 3 years ago

@GeeksforGeeks
This partition function gives O(n^2) in all cases.
It would be better to employ selection sort than to use this partition function (because of the recursion cost).
Below, i provide a pivoted partition function with complexity O(nlogn).

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


struct dnode
{
    int info;
    struct dnode *b;
    struct dnode *f;
};


typedef struct dnode *Dnode;
```

see more

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Scott Shipp • 3 years ago

My thought is that this is good overall, but I wanted to mention variable names could be clearer. Using "l" and "h" for start and end indices is the kind of thing that really interferes with code readability and maintainability.

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abhishek08aug • 3 years ago

Intelligent :D

• Reply • Share ›

Ronny abhishek08aug • 3 years ago

You seem to have read all the posts/topics of geeksforgeeks.
Cool stuff.
Maybe I should say it for you : "Intelligent :)"

4 • Reply • Share ›

Srinath • 3 years ago

I have one serious doubt...
you are swapping just the data field,in this case it is just a single int but I dont think that is a good practice.You should swap the entire node by adjusting pointers so that no matter what the object that the linked list is holding the code doesn't change...

You didn't use previous pointer except in one or two cases...
To remove it completely,in partition function store pointer to last element of left partition before swapping h->data and i->data..then return this pointer instead of i.

then just change quicksort function to accomodate this.

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