HeapSort

Heap sort is a comparison based sorting technique based on Binary Heap data structure. It is similar to selection sort where we first find the maximum element and place the maximum element at the end. We repeat the same process for remaining element.

What is Binary Heap?
Let us first define a Complete Binary Tree. A complete binary tree is a binary tree in which every level, except possibly the last, is completely filled, and all nodes are as far left as possible (Source Wikipedia)

A Binary Heap is a Complete Binary Tree where items are stored in a special order such that value in a parent node is greater(or smaller) than the values in its two children nodes. The former is called as max heap and the latter is called min heap. The heap can be represented by binary tree or array.

Why array based representation for Binary Heap?
Since a Binary Heap is a Complete Binary Tree, it can be easily represented as array and array based representation is space efficient. If the parent node is stored at index I, the left child can be calculated by 2 * I + 1 and right child by 2 * I + 2 (assuming the indexing starts at 0).

Heap Sort Algorithm for sorting in increasing order:
1. Build a max heap from the input data.
2. At this point, the largest item is stored at the root of the heap. Replace it with the last item of the heap followed by reducing the size of heap by 1. Finally, heapify the root of tree.
3. Repeat above steps while size of heap is greater than 1.

How to build the heap?
Heapify procedure can be applied to a node only if its children nodes are heapified. So the heapification must be performed in the bottom up order.

Lets understand with the help of an example:

```
Input data: 4, 10, 3, 5, 1
         4(0)
        /   \
     10(1)   3(2)
    /   \
 5(3)    1(4)

The numbers in bracket represent the indices in the array
representation of data.

Applying heapify procedure to index 1:
         4(0)
        /   \
    10(1)    3(2)
    /   \
5(3)    1(4)
```

```
Applying heapify procedure to index 0:
        10(0)
        /  \
     5(1)  3(2)
    /   \
 4(3)    1(4)
The heapify procedure calls itself recursively to build heap
 in top down manner.
```

Recommended: Please solve it on "*PRACTICE*" first, before moving on to the solution.

C++

```
// C++ program for implementation of Heap Sort
#include <iostream>

using namespace std;

// To heapify a subtree rooted with node i which is
// an index in arr[]. n is size of heap
void heapify(int arr[], int n, int i)
{
    int largest = i; // Initialize largest as root
    int l = 2*i + 1; // left = 2*i + 1
    int r = 2*i + 2; // right = 2*i + 2

    // If left child is larger than root
    if (l < n && arr[l] > arr[largest])
        largest = l;

    // If right child is larger than largest so far
    if (r < n && arr[r] > arr[largest])
        largest = r;

    // If largest is not root
    if (largest != i)
    {
        swap(arr[i], arr[largest]);

        // Recursively heapify the affected sub-tree
        heapify(arr, n, largest);
    }
}

// main function to do heap sort
void heapSort(int arr[], int n)
{
    // Build heap (rearrange array)
    for (int i = n / 2 - 1; i >= 0; i--)
        heapify(arr, n, i);

    // One by one extract an element from heap
    for (int i=n-1; i>=0; i--)
    {
        // Move current root to end
        swap(arr[0], arr[i]);

        // call max heapify on the reduced heap
        heapify(arr, i, 0);
    }
}

/* A utility function to print array of size n */
void printArray(int arr[], int n)
{
    for (int i=0; i<n; ++i)
        cout << arr[i] << " ";
    cout << "\n";
}

// Driver program
int main()
{
    int arr[] = {12, 11, 13, 5, 6, 7};
    int n = sizeof(arr)/sizeof(arr[0]);
```

```
    heapSort(arr, n);

    cout << "Sorted array is \n";
    printArray(arr, n);
}
```

Java

```
// Java program for implementation of Heap Sort
public class HeapSort
{
    public void sort(int arr[])
    {
        int n = arr.length;

        // Build heap (rearrange array)
        for (int i = n / 2 - 1; i >= 0; i--)
            heapify(arr, n, i);

        // One by one extract an element from heap
        for (int i=n-1; i>=0; i--)
        {
            // Move current root to end
            int temp = arr[0];
            arr[0] = arr[i];
            arr[i] = temp;

            // call max heapify on the reduced heap
            heapify(arr, i, 0);
        }
    }

    // To heapify a subtree rooted with node i which is
    // an index in arr[]. n is size of heap
    void heapify(int arr[], int n, int i)
    {
        int largest = i; // Initialize largest as root
        int l = 2*i + 1; // left = 2*i + 1
        int r = 2*i + 2; // right = 2*i + 2

        // If left child is larger than root
        if (l < n && arr[l] > arr[largest])
            largest = l;

        // If right child is larger than largest so far
        if (r < n && arr[r] > arr[largest])
            largest = r;

        // If largest is not root
        if (largest != i)
        {
            int swap = arr[i];
            arr[i] = arr[largest];
            arr[largest] = swap;

            // Recursively heapify the affected sub-tree
            heapify(arr, n, largest);
        }
    }

    /* A utility function to print array of size n */
    static void printArray(int arr[])
    {
        int n = arr.length;
        for (int i=0; i<n; ++i)
            System.out.print(arr[i]+" ");
        System.out.println();
    }

    // Driver program
    public static void main(String args[])
    {
        int arr[] = {12, 11, 13, 5, 6, 7};
        int n = arr.length;

        HeapSort ob = new HeapSort();
        ob.sort(arr);
```

```
        System.out.println("Sorted array is");
        printArray(arr);
    }
}
```

Python

```
# Python program for implementation of heap Sort

# To heapify subtree rooted at index i.
# n is size of heap
def heapify(arr, n, i):
    largest = i # Initialize largest as root
    l = 2 * i + 1     # left = 2*i + 1
    r = 2 * i + 2     # right = 2*i + 2

    # See if left child of root exists and is
    # greater than root
    if l < n and arr[i] < arr[l]:
        largest = l

    # See if right child of root exists and is
    # greater than root
    if r < n and arr[largest] < arr[r]:
        largest = r

    # Change root, if needed
    if largest != i:
        arr[i],arr[largest] = arr[largest],arr[i] # swap

        # Heapify the root.
        heapify(arr, n, largest)

# The main function to sort an array of given size
def heapSort(arr):
    n = len(arr)

    # Build a maxheap.
    for i in range(n, -1, -1):
        heapify(arr, n, i)

    # One by one extract elements
    for i in range(n-1, 0, -1):
        arr[i], arr[0] = arr[0], arr[i] # swap
        heapify(arr, i, 0)

# Driver code to test above
arr = [ 12, 11, 13, 5, 6, 7]
heapSort(arr)
n = len(arr)
print ("Sorted array is")
for i in range(n):
    print ("%d" %arr[i]),
# This code is contributed by Mohit Kumra
```

C#

```
// C# program for implementation of Heap Sort
using System;

public class HeapSort
{
    public void sort(int[] arr)
    {
        int n = arr.Length;

        // Build heap (rearrange array)
        for (int i = n / 2 - 1; i >= 0; i--)
            heapify(arr, n, i);

        // One by one extract an element from heap
        for (int i=n-1; i>=0; i--)
        {
            // Move current root to end
            int temp = arr[0];
            arr[0] = arr[i];
```

```
            arr[i] = temp;

            // call max heapify on the reduced heap
            heapify(arr, i, 0);
        }
    }

    // To heapify a subtree rooted with node i which is
    // an index in arr[]. n is size of heap
    void heapify(int[] arr, int n, int i)
    {
        int largest = i; // Initialize largest as root
        int l = 2*i + 1; // left = 2*i + 1
        int r = 2*i + 2; // right = 2*i + 2

        // If left child is larger than root
        if (l < n && arr[l] > arr[largest])
            largest = l;

        // If right child is larger than largest so far
        if (r < n && arr[r] > arr[largest])
            largest = r;

        // If largest is not root
        if (largest != i)
        {
            int swap = arr[i];
            arr[i] = arr[largest];
            arr[largest] = swap;

            // Recursively heapify the affected sub-tree
            heapify(arr, n, largest);
        }
    }

    /* A utility function to print array of size n */
    static void printArray(int[] arr)
    {
        int n = arr.Length;
        for (int i=0; i<n; ++i)
            Console.Write(arr[i]+" ");
        Console.Read();
    }

    // Driver program
    public static void Main()
    {
        int[] arr = {12, 11, 13, 5, 6, 7};
        int n = arr.Length;

        HeapSort ob = new HeapSort();
        ob.sort(arr);

        Console.WriteLine("Sorted array is");
        printArray(arr);
    }
}

// This code is contributed
// by Akanksha Rai(Abby_akku)
```

PHP

```
<?php

// Php program for implementation of Heap Sort

// To heapify a subtree rooted with node i which is
// an index in arr[]. n is size of heap
function heapify(&$arr, $n, $i)
{
    $largest = $i; // Initialize largest as root
    $l = 2*$i + 1; // left = 2*i + 1
    $r = 2*$i + 2; // right = 2*i + 2

    // If left child is larger than root
    if ($l < $n && $arr[$l] > $arr[$largest])
        $largest = $l;
```

```
    // If right child is larger than largest so far
    if ($r < $n && $arr[$r] > $arr[$largest])
        $largest = $r;

    // If largest is not root
    if ($largest != $i)
    {
        $swap = $arr[$i];
        $arr[$i] = $arr[$largest];
        $arr[$largest] = $swap;

        // Recursively heapify the affected sub-tree
        heapify($arr, $n, $largest);
    }
}

// main function to do heap sort
function heapSort(&$arr, $n)
{
    // Build heap (rearrange array)
    for ($i = $n / 2 - 1; $i >= 0; $i--)
        heapify($arr, $n, $i);

    // One by one extract an element from heap
    for ($i = $n-1; $i >= 0; $i--)
    {
        // Move current root to end
        $temp = $arr[0];
            $arr[0] = $arr[$i];
            $arr[$i] = $temp;

        // call max heapify on the reduced heap
        heapify($arr, $i, 0);
    }
}

/* A utility function to print array of size n */
function printArray(&$arr, $n)
{
    for ($i = 0; $i < $n; ++$i)
        echo ($arr[$i]." ") ;

}

// Driver program
    $arr = array(12, 11, 13, 5, 6, 7);
    $n = sizeof($arr)/sizeof($arr[0]);

    heapSort($arr, $n);

    echo 'Sorted array is ' . "\n";

    printArray($arr , $n);

// This code is contributed by Shivi_Aggarwal
?>
```

Output:

```
Sorted array is
5 6 7 11 12 13
```

Here is previous C code for reference.

Notes:

Heap sort is an in-place algorithm.

Its typical implementation is not stable, but can be made stable (See this)

Time Complexity: Time complexity of heapify is O(Logn). Time complexity of createAndBuildHeap() is O(n) and overall time complexity of Heap Sort is O(nLogn).

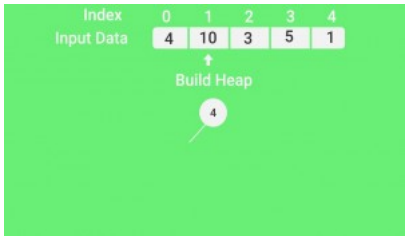
Applications of HeapSort

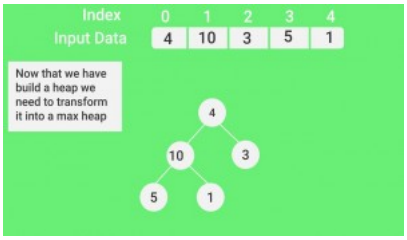
1. Sort a nearly sorted (or K sorted) array

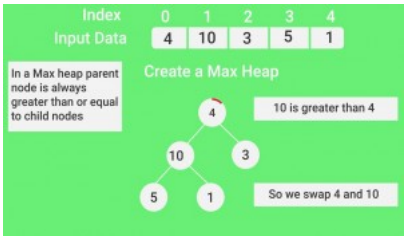
2. k largest(or smallest) elements in an array

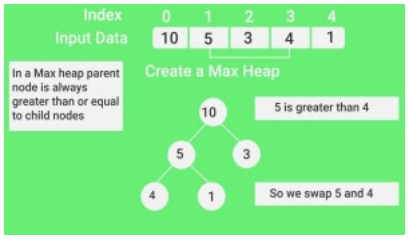
Heap sort algorithm has limited uses because Quicksort and Mergesort are better in practice. Nevertheless, the Heap data structure itself is enormously used. See Applications of Heap Data Structure

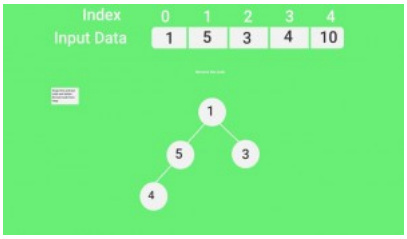
Snapshots:

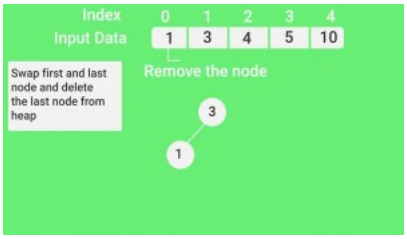












Quiz on Heap Sort

Other Sorting Algorithms on GeeksforGeeks/GeeksQuiz:

QuickSort, Selection Sort, Bubble Sort, Insertion Sort, Merge Sort, Heap Sort, QuickSort, Radix Sort, Counting Sort, Bucket Sort, ShellSort, Comb Sort, Pigeonhole Sort

Coding practice for sorting.

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Improved By : Shivi_Aggarwal, Akanksha_Rai, RishiAdvani, Vibhav Gupta

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