Practical 1 : BFS (Sequential and Parallel)

```
#include <iostream>
#include <queue>
#include <omp.h>
#include <chrono>
#include <cstdlib>

using namespace std;
using namespace std::chrono;

class node
{
public:
   node *left, *right;
   int data;
};

node *insert(node *root, int data)
{
   if (!root)
   {
      root = new node;
      root->left = NULL;
      root->right = NULL;
      root->data = data;
      return root;
   }

   queue<node *> q;
   q.push(root);

   while (!q.empty())
   {
      node *temp = q.front();
      q.pop();

      if (temp->left == NULL)
      {
         temp->left = new node;
         temp->left->left = NULL;
         temp->left->right = NULL;
         temp->left->data = data;
         return root;
      }
      else
      {
         q.push(temp->left);
      }

      if (temp->right == NULL)
      {
         temp->right = new node;
         temp->right->left = NULL;
         temp->right->right = NULL;
         temp->right->data = data;
         return root;
      }
      else
      {
         q.push(temp->right);
      }
   }

   return root;
}

void bfs(node *head)
{
   queue<node *> q;
```

```
    q.push(head);

    while (!q.empty())
    {
        node *currNode = q.front();
        q.pop();
        cout<<currNode->data<<", ";

        if (currNode->left)
            q.push(currNode->left);
        if (currNode->right)
            q.push(currNode->right);
    }
}

int main()
{
    cout << "This is Atharva Pingale's Code";
    cout << "\nPractical 1 : BFS ( Sequential and Parallel )";
    node *root = NULL;
    node *root2 = NULL;
    int data;
    long int n, i;
                double start_time, end_time;
    cout << "\n\nEnter number of nodes : ";
    cin >> n;
    for (i = 0; i < n; i++)
    {
        int random_value = (rand() % (999999 - 999 + 1) + 999);
        root = insert(root, random_value);
        root2 = insert(root2, random_value);
    }

    // Sequential BFS timing
    start_time = omp_get_wtime();
    bfs(root);
    end_time = omp_get_wtime();
    double seq_time = end_time - start_time;

    // Parallel BFS timing
    start_time = omp_get_wtime();
    queue<node *> q;
    q.push(root2);

    bool empty_flag = false;

#pragma omp parallel
    {
        while (true)
        {
            node *currNode;
            bool local_empty_flag = false;
            #pragma omp critical
            {
                if (!q.empty())
                {
                    currNode = q.front();
                    q.pop();
                }
                else
                {
                    local_empty_flag = true;
                }
            }

            #pragma omp critical
            {
                empty_flag = empty_flag || local_empty_flag;
            }

            if (empty_flag)
```

```
            break;

        #pragma omp single nowait
        {
            cout << "\t" << currNode->data; // Print the node
        }

        #pragma omp critical
        {
            if (currNode->left)
                q.push(currNode->left); // Push the left child
            if (currNode->right)
                q.push(currNode->right); // Push the right child
        }
    }
  }

  end_time = omp_get_wtime();
  double parallel_time = end_time - start_time;

  cout << "\n\nSequential BFS Time: " << seq_time << " seconds";
  cout << "\n\nParallel BFS Time: " << parallel_time << " seconds\n";

  delete root;
  delete root2;

  return 0;
}
```

Output :

```
athar@LAPTOP-U0997R48 MINGW64 /d/GitHub/BE-8th-Semester/hpc_practicals (main)
$ g++ -fopenmp BFS.cpp -o BFS

athar@LAPTOP-U0997R48 MINGW64 /d/GitHub/BE-8th-Semester/hpc_practicals (main)
$ ./BFS
This is Atharva Pingale's Code
Practical 1 : BFS ( Sequential and Parallel )

Enter number of nodes : 500
1040, 19466, 7333, 27499, 20168, 16723, 12477, 30357, 27961, 25463, 6704, 29144, 24280, 17826, 10960, 1490, 3994, 12941, 5826, 6435, 33390, 15603, 4901, 1152, 1291, 13381, 18420, 19715, 20717, 20894, 6446, 22725, 1
5770, 12537, 2868, 20911, 26666, 27298, 18034, 10893, 29702, 24810, 32321, 31332, 18672, 5663, 16140, 8710, 29252, 7867, 26546, 28643, 33661, 33756, 21036, 13858, 9722, 10740, 28528, 1777, 13315, 4034, 23189, 2841,
 1287, 31105, 10039, 9941, 20263, 23647, 28445, 24804, 16889, 7728, 25369, 16349, 16005, 32100, 25392, 4547, 20628, 13622, 25083, 20953, 19755, 12839, 5965, 8375, 14930, 27307, 17943, 33438, 25625, 12322, 6536, 225
37, 17117, 3081, 23928, 17540, 5832, 32114, 5638, 30657, 23703, 10929, 14976, 3305, 32672, 23385, 6020, 29744, 27923, 20071, 7269, 6828, 27776, 16572, 6096, 17511, 24985, 14289, 10160, 19635, 23354, 25766, 24654, 1
6573, 5030, 13051, 28349, 2149, 17940, 22723, 14965, 4429, 32106, 31190, 19006, 12336, 16456, 13286, 28752, 11382, 15944, 9908, 33208, 10757, 25220, 19587, 7421, 25945, 28505, 14029, 17412, 30167, 1899, 33590, 1976
1, 2654, 18409, 7358, 28623, 21536, 22547, 7482, 28594, 5040, 4601, 25349, 11290, 31835, 10373, 12019, 5595, 25020, 28347, 24198, 20667, 25483, 9280, 5733, 1052, 2998, 27417, 28937, 7899, 4787, 19126, 1466, 4727, 1
5892, 25647, 23482, 18806, 3420, 15309, 7616, 23812, 10513, 15308, 8615, 19934, 18450, 21599, 6248, 17518, 32555, 23797, 31302, 7223, 12007, 6843, 33608, 15988, 33701, 4194, 21484, 4092, 15342, 31522, 2586, 30313,
 10502, 8447, 26199, 14457, 7617, 21579, 20795, 15797, 16280, 20588, 21797, 29008, 28156, 21471, 24621, 19537, 13291, 7037, 25178, 19189, 30656, 8957, 7190, 20814, 23887, 20155, 12510, 17201, 3633, 25271, 21054, 213
27, 23645, 27361, 5885, 19874, 29432, 30868, 21141, 24843, 2415, 22880, 32997, 11321, 19650, 11020, 6698, 4556, 29475, 28891, 25388, 6074, 11711, 3599, 3509, 22002, 27868, 18860, 15687, 14400, 10788, 16254, 17422,
 6001, 11584, 25181, 11284, 28087, 32425, 29616, 24756, 10831, 31931, 5168, 3153, 26720, 18188, 20975, 32328, 3367, 29691, 22424, 11554, 4433, 17548, 8440, 10511, 31144, 19059, 22717, 4752, 17138, 13422, 17278, 2699
5, 17686, 13528, 23548, 18436, 20865, 13948, 1192, 24194, 4296, 21415, 29285, 17104, 25487, 17281, 13454, 26733, 19113, 12700, 32315, 21670, 6785, 13262, 5312, 25354, 32184, 21052, 1911, 11807, 2831, 21944, 5312, 2
8755, 29320, 20557, 24645, 28981, 1480, 5143, 24195, 21221, 8128, 3160, 6534, 21449, 12172, 11465, 13043, 22658, 27291, 27438, 18252, 21023, 27153, 30509, 5744, 21648, 14185, 9312, 5473, 29021, 3167, 15017, 19786,
 10904, 18957, 8390, 11201, 4624, 27476, 5413, 10313, 26823, 30333, 26873, 25371, 21158, 12832, 29069, 8486, 29296, 8517, 9176, 18772, 33269, 2762, 3667, 18191, 14984, 4101, 9479, 30212, 8626, 5801, 5098, 31526, 362
4, 2542, 2923, 12022, 30971, 14060, 15180, 32002, 28431, 18504, 28592, 23724, 14030, 9491, 1141, 18221, 32285, 14063, 8899, 20186, 9359, 23412, 31973, 15269, 30169, 1234, 31832, 20710, 26759, 19895, 5666, 8284, 135
49, 1139, 14693, 3694, 22623, 29018, 3124, 27575, 22693, 23657, 27301, 18370, 23465, 5677, 23592, 24850, 26483, 2017, 29463, 22118, 24151, 3799, 19086, 32059, 2925, 10009, 5756, 33169, 21314, 10575, 31226, 13042, 2
3757, 8163, 6108, 8881, 18085, 30564, 4486, 30576, 15473, 3624, 26626, 6628, 32927, 26422, 29519, 7901, 15961, 1122, 25595, 4736, 14260, 11194, 33524,  1040

Sequential BFS Time: 0.072 seconds

Parallel BFS Time: 0 seconds

athar@LAPTOP-U0997R48 MINGW64 /d/GitHub/BE-8th-Semester/hpc_practicals (main)
$
```

Sequential BFS Time : 0.072 seconds
Parallel BFS Time : 0 seconds

```
athar@LAPTOP-U0997R48 MINGW64 /d/GitHub/BE-8th-Semester/hpc_practicals/Codes (main)
$ g++ -fopenmp BFS.cpp -o BFS

athar@LAPTOP-U0997R48 MINGW64 /d/GitHub/BE-8th-Semester/hpc_practicals/Codes (main)
$ ./BFS
This is Atharva Pingale's Code
Practical 1 : BFS ( Sequential and Parallel )

Enter number of nodes : 935
1040, 19466, 7333, 27499, 20168, 16723, 12477, 30357, 27961, 25463, 6704, 29144, 24280, 17826, 10960, 1490, 3994, 12941, 5826, 6435, 33390, 15603, 4901, 1152, 1291, 13381, 18420, 19715, 20717, 20894, 6446, 22725, 1
5770, 12537, 2868, 20911, 26666, 27298, 18034, 10893, 29702, 24810, 32321, 31332, 18672, 5663, 16140, 8710, 29252, 7867, 26546, 28643, 33661, 33756, 21036, 13858, 9722, 10740, 28528, 1777, 13315, 4034, 23189, 2841,
 1287, 31105, 10039, 9941, 20263, 23647, 28445, 24804, 16889, 7728, 25369, 16349, 16005, 32100, 25392, 4547, 20628, 13622, 25083, 20953, 19755, 12839, 5965, 8375, 14930, 27307, 17943, 33438, 25625, 12322, 6536, 225
37, 17117, 3081, 23928, 17540, 5832, 32114, 5638, 30657, 23703, 10929, 14976, 3305, 32672, 23385, 6020, 29744, 27923, 20071, 7269, 6828, 27776, 16572, 6096, 17511, 24985, 14280, 10160, 19635, 23354, 25766, 24654, 1
6573, 5030, 13051, 28349, 2149, 17940, 22723, 14965, 4429, 32106, 31190, 19006, 12336, 16456, 13286, 28752, 11382, 15944, 9908, 33208, 10757, 25220, 19587, 7421, 25945, 28505, 14029, 17412, 30167, 1899, 33590, 1976
1, 2654, 18409, 7358, 28623, 21536, 22547, 7482, 28594, 5040, 4601, 25349, 11290, 31835, 10373, 12019, 5595, 25020, 28347, 24198, 20667, 25483, 9280, 5733, 1052, 2998, 27417, 28937, 7899, 4787, 19126, 1466, 4727, 1
5892, 25647, 23482, 18806, 3420, 15309, 7616, 23812, 10513, 15308, 8615, 19934, 18450, 21599, 6248, 17518, 32555, 23797, 31302, 7223, 12007, 6843, 33608, 15988, 33701, 4194, 21484, 4092, 15342, 31522, 2586, 30313,
10502, 8447, 26199, 14457, 7617, 21579, 20795, 15797, 16280, 20588, 21797, 29008, 28156, 21471, 24621, 19537, 13291, 7037, 25178, 19189, 30656, 8957, 7190, 20814, 23887, 20155, 12510, 17201, 3633, 25271, 21054, 213
27, 23645, 27361, 5885, 19874, 29432, 30868, 21141, 24843, 2415, 22880, 32997, 11321, 19650, 11020, 6698, 4556, 29475, 28891, 25388, 6074, 11711, 3599, 3509, 22002, 27868, 18860, 15687, 14400, 10788, 16254, 17422,
6001, 11584, 25181, 11284, 28087, 32425, 29616, 24756, 10831, 31931, 5168, 3153, 26720, 18188, 20975, 32328, 3367, 29691, 22424, 11554, 4433, 17548, 8440, 10511, 31144, 19059, 22717, 4752, 17138, 13422, 17278, 2699
5, 17686, 13528, 23548, 18436, 20865, 13948, 1192, 24194, 4296, 21415, 29285, 17104, 25487, 17281, 13454, 26733, 19113, 12700, 32315, 21670, 6785, 13262, 5312, 25354, 32184, 21052, 1911, 11807, 2831, 21944, 5312, 2
8755, 29320, 20557, 24645, 28981, 1480, 5143, 24195, 21221, 8128, 3160, 6534, 21449, 12172, 11465, 13043, 22658, 27291, 27438, 18252, 21023, 27153, 30509, 5744, 21648, 14185, 9312, 5473, 29021, 3167, 15017, 19786,
10904, 18957, 8390, 11201, 4624, 27476, 5413, 10313, 26823, 30333, 26873, 25371, 21158, 12832, 29069, 8486, 29296, 8517, 9176, 18772, 33269, 2762, 3667, 18191, 14984, 4101, 9479, 30212, 8626, 5801, 5098, 31526, 362
4, 2542, 2923, 12022, 30971, 14060, 15180, 32002, 28431, 18504, 28592, 23724, 14030, 9491, 1141, 18221, 32285, 14863, 8899, 20186, 9359, 23412, 31973, 15269, 30169, 1234, 31832, 20710, 26759, 19895, 5666, 8284, 135
49, 1139, 14693, 3694, 22623, 29018, 3124, 27575, 22693, 23657, 27301, 18370, 23465, 5677, 23592, 24850, 26483, 2017, 29463, 22118, 24151, 3799, 19086, 32059, 2925, 10009, 5756, 33169, 21314, 10575, 31226, 13042, 2
3757, 8163, 6108, 8881, 18085, 30564, 4486, 30576, 15473, 3624, 26626, 6628, 32927, 26422, 29519, 7901, 15961, 1122, 25595, 4736, 14260, 11194, 33524, 2263, 9259, 7201, 9115, 6029, 21325, 30010, 31770, 7410, 26546,
 22152, 22519, 30789, 15923, 31187, 22762, 5939, 21850, 19661, 14828, 31899, 18712, 19957, 18577, 9364, 14006, 12476, 2199, 27057, 7438, 3302, 13759, 20356, 3323, 7476, 6107, 22112, 15886, 20800, 23849, 15459, 2342
7, 13992, 28383, 20404, 7539, 32110, 29703, 13834, 33355, 7071, 30349, 19822, 15484, 21555, 24215, 2625, 10356, 9525, 14356, 30336, 24270, 24868, 30360, 13895, 14021, 30616, 11111, 13716, 19695, 12584, 25040, 25422
, 25128, 25228, 5564, 7558, 9931, 23295, 30854, 13052, 17961, 4583, 30733, 7653, 17971, 22456, 15368, 23531, 3962, 3606, 3482, 1910, 12634, 11066, 23847, 5674, 13937, 3222, 23141, 24753, 7510, 23740, 21174, 22458,
18824, 4220, 18869, 2625, 32933, 16204, 32782, 24849, 18397, 23278, 23700, 13192, 13733, 2636, 27533, 6555, 2992, 11175, 26704, 7961, 11547, 16880, 1299, 15412, 17640, 20854, 25854, 14141, 12461, 28610, 31876, 2142
3, 33677, 2751, 19442, 29295, 13672, 11039, 10312, 1874, 21071, 13817, 1609, 2016, 15931, 29111, 31694, 14168, 24830, 21039, 27487, 29684, 20089, 20496, 3588, 26989, 16144, 20352, 28313, 19650, 27739, 23043, 12257,
 1334, 9758, 12191, 8604, 26263, 13180, 29502, 4828, 24774, 21607, 30291, 6996, 18548, 30555, 26560, 32626, 7466, 30540, 27128, 32239, 28812, 30173, 21600, 7076, 21214, 9682, 9212, 24991, 26823, 6600, 24391, 16758,
 3669, 27427, 29026, 5803, 11074, 19785, 16407, 25969, 7286, 24846, 32603, 1502, 22220, 23662, 6705, 3362, 10089, 23170, 20488, 19239, 13163, 26541, 8618, 21912, 8530, 7703, 32817, 10231, 1749, 26204, 5974, 2538, 1
302, 12421, 22097, 12246, 14583, 14647, 3970, 18863, 23912, 12074, 22544, 29711, 18545, 19677, 2768, 16261, 9518, 14984, 29288, 16943, 3864, 19539, 24244, 26587, 29317, 28869, 10600, 29322, 22131, 25471, 28151, 260
85, 29569, 30762, 30900, 18102, 15422, 4526, 12599, 27968, 15014, 6564, 1027, 22542, 26346, 3087, 3942, 13636, 23408, 27462, 6048, 5680, 2587, 12341, 1607, 33059, 22220, 2757, 30953, 21887, 15145, 1689, 8948, 13842
, 22429, 26619, 1747, 28866, 5535, 21782, 19034, 33225, 16184, 8037, 10852, 26628, 12223, 16747, 20922, 4358, 33256, 25765, 5943, 15954, 24317, 33725, 26410, 22024, 21354, 32000, 23548, 10495, 19583, 10514, 18963,
24341, 9074, 18912, 17141, 32195, 22947, 26071, 21425, 15605, 27172, 25428, 33403, 7704, 21625, 30811, 20374, 31092, 17564, 17035, 15735, 30140, 31813, 6993, 9255, 7651, 24935, 31837, 21481, 2354, 22014, 2130, 1922
9, 18840, 15624, 3010, 33636, 5185, 20689, 2649, 6661, 22633, 11892, 11352, 22415, 14451, 15007, 8261, 23232, 6453, 17302, 17633, 27302, 15255, 1147, 12123, 13316, 5212, 28108, 25027, 30199, 22079, 22317, 17857, 25
049, 25154, 32360, 16263, 12902, 4675, 30642, 27908, 15901, 4560, 29488, 25947, 2281, 14652, 31673, 3219, 6401, 7922, 4830, 20368, 4877, 21258, 20007, 23618, 24970, 31002, 22944, 10780, 27503, 13391, 33684, 26312,
7697, 6588, 13721, 6937, 20036, 7409, 32460, 7233, 13507, 10960, 4958, 7492, 2514,      1040

Sequential BFS Time: 0.192 seconds

Parallel BFS Time: 0 seconds
```

Sequential BFS Time : 0.192 seconds
Parallel BFS Time : 0 seconds

```
athar@LAPTOP-U0997R48 MINGW64 /d/GitHub/BE-8th-Semester/hpc_practicals/Codes (main)
$ g++ -fopenmp BFS.cpp -o BFS

athar@LAPTOP-U0997R48 MINGW64 /d/GitHub/BE-8th-Semester/hpc_practicals/Codes (main)
$ ./BFS
This is Atharva Pingale's Code
Practical 1 : BFS ( Sequential and Parallel )

Enter number of nodes : 510
1040, 19466, 7333, 27499, 20168, 16723, 12477, 30357, 27961, 25463, 6704, 29144, 24280, 17826, 10960, 1490, 3994, 12941, 5826, 6435, 33390, 15603, 4901, 1152, 1291, 13381, 18420, 19715, 20717, 20894, 6446, 22725, 1
5770, 12537, 2868, 20911, 26666, 27298, 18034, 10893, 29702, 24810, 32321, 31332, 18672, 5663, 16140, 8710, 29252, 7867, 26546, 28643, 33661, 33756, 21036, 13858, 9722, 10740, 28528, 1777, 13315, 4034, 23189, 2841,
 1287, 31105, 10039, 9941, 20263, 23647, 28445, 24804, 16889, 7728, 25369, 16349, 16005, 32100, 25392, 4547, 20628, 13622, 25083, 20953, 19755, 12839, 5965, 8375, 14930, 27307, 17943, 33438, 25625, 12322, 6536, 225
37, 17117, 3081, 23928, 17540, 5832, 32114, 5638, 30657, 23703, 10929, 14976, 3305, 32672, 23385, 6020, 29744, 27923, 20071, 7269, 6828, 27776, 16572, 6096, 17511, 24985, 14280, 10160, 19635, 23354, 25766, 24654, 1
6573, 5030, 13051, 28349, 2149, 17940, 22723, 14965, 4429, 32106, 31190, 19006, 12336, 16456, 13286, 28752, 11382, 15944, 9908, 33208, 10757, 25220, 19587, 7421, 25945, 28505, 14029, 17412, 30167, 1899, 33590, 1976
1, 2654, 18409, 7358, 28623, 21536, 22547, 7482, 28594, 5040, 4601, 25349, 11290, 31835, 10373, 12019, 5595, 25020, 28347, 24198, 20667, 25483, 9280, 5733, 1052, 2998, 27417, 28937, 7899, 4787, 19126, 1466, 4727, 1
5892, 25647, 23482, 18806, 3420, 15309, 7616, 23812, 10513, 15308, 8615, 19934, 18450, 21599, 6248, 17518, 32555, 23797, 31302, 7223, 12007, 6843, 33608, 15988, 33701, 4194, 21484, 4092, 15342, 31522, 2586, 30313,
10502, 8447, 26199, 14457, 7617, 21579, 20795, 15797, 16280, 20588, 21797, 29008, 28156, 21471, 24621, 19537, 13291, 7037, 25178, 19189, 30656, 8957, 7190, 20814, 23887, 20155, 12510, 17201, 3633, 25271, 21054, 213
27, 23645, 27361, 5885, 19874, 29432, 30868, 21141, 24843, 2415, 22880, 32997, 11321, 19650, 11020, 6698, 4556, 29475, 28891, 25388, 6074, 11711, 3599, 3509, 22002, 27868, 18860, 15687, 14400, 10788, 16254, 17422,
6001, 11584, 25181, 11284, 28087, 32425, 29616, 24756, 10831, 31931, 5168, 3153, 26720, 18188, 20975, 32328, 3367, 29691, 22424, 11554, 4433, 17548, 8440, 10511, 31144, 19059, 22717, 4752, 17138, 13422, 17278, 2699
5, 17686, 13528, 23548, 18436, 20865, 13948, 1192, 24194, 4296, 21415, 29285, 17104, 25487, 17281, 13454, 26733, 19113, 12700, 32315, 21670, 6785, 13262, 5312, 25354, 32184, 21052, 1911, 11807, 2831, 21944, 5312, 2
8755, 29320, 20557, 24645, 28981, 1480, 5143, 24195, 21221, 8128, 3160, 6534, 21449, 12172, 11465, 13043, 22658, 27291, 27438, 18252, 21023, 27153, 30509, 5744, 21648, 14185, 9312, 5473, 29021, 3167, 15017, 19786,
10904, 18957, 8390, 11201, 4624, 27476, 5413, 10313, 26823, 30333, 26873, 25371, 21158, 12832, 29069, 8486, 29296, 8517, 9176, 18772, 33269, 2762, 3667, 18191, 14984, 4101, 9479, 30212, 8626, 5801, 5098, 31526, 362
4, 2542, 2923, 12022, 30971, 14060, 15180, 32002, 28431, 18504, 28592, 23724, 14030, 9491, 1141, 18221, 32285, 14863, 8899, 20186, 9359, 23412, 31973, 15269, 30169, 1234, 31832, 20710, 26759, 19895, 5666, 8284, 135
49, 1139, 14693, 3694, 22623, 29018, 3124, 27575, 22693, 23657, 27301, 18370, 23465, 5677, 23592, 24850, 26483, 2017, 29463, 22118, 24151, 3799, 19086, 32059, 2925, 10009, 5756, 33169, 21314, 10575, 31226, 13042, 2
3757, 8163, 6108, 8881, 18085, 30564, 4486, 30576, 15473, 3624, 26626, 6628, 32927, 26422, 29519, 7901, 15961, 1122, 25595, 4736, 14260, 11194, 33524, 2263, 9259, 7201, 9115, 6029, 21325, 30010, 31770, 7410, 26546,
       1040

Sequential BFS Time: 0.106 seconds

Parallel BFS Time: 0 seconds
```

Sequential BFS Time : 0.106 seconds
Parallel BFS Time : 0 seconds