The Implementation of KL Algorithm in C++

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Kernighan-Lin (KL) Algorithm:

The Kernighan-Lin (KL) algorithm is a heuristic algorithm (an iterative improvement technique) for finding partitions of graphs. It's a two-way partitioning algorithm and the partitions must be balanced (of equal size). The algorithm has important applications in the layout of digital circuits and components in VLSI. The pseudocode of KL algorithm is given below.

```
Procedure: KL heuristic (G);
  begin-1 // initial partition obtained randomly  or by constructive techniques
    bipartition G into two groups V1 and V2, with |V1| = |V2| ± 1;
    repeat-2 // main pass
      for i = 1 to n/2 do
        begin-3
          find a pair of unlocked vertices v_ai ∈ V_1 and v_bi ∈ V_2 whose exchange
          gives largest decrease in cut-cost or smallest increase;
          mark v_ai and v_bi as locked and store the gain g_i ;
          update D-values of all remaining unlocked vertices; // tentative exchange
        end-3
      find k such that is Σ_{i=1..k} g_i=Gain_k maximized;
      if Gain_k > 0 then // actual exchange
        move v_a1,...,v_ak from V_1 to V_2 and v_b1,...,v_bk from V_2 to V_1
    until-2 Gain_k is less than or equal to zero
  end-1
// key point: accepting negative gains occasionally enables algorithm
// to get out of local (gain) maxima (a.k.a. hill climbing). Eventually
// it may lead to global maximum (gain)
```

Figure 1: The pseudocode of KL algorithm [2]

Comments on Implementation:

This project was implemented in C++ language using Code::Blocks. Array and many other Data Structures were used to complete the assignment. C++ Standard Template Library (STL), such as vectors, iterator, map, and pair were also used. Details are given in the code's comment section.

Result:

For the first circuit,

The number of edges: 621

The number of nodes: 153

Initial Cut Cost: 546

Main Pass Number	**Relative Statistics**
1	Number of Steps: 27 The Maximum Gain: 203 Current Cut Cost: 141 KL Algorithm Continues
2	Number of Steps: 3 The Maximum Gain: 3 Current Cut Cost: 139 KL Algorithm Continues
3	Number of Steps: 1 The Maximum Gain: 2 Current Cut Cost: 135 KL Algorithm Continues
4	Number of Steps: 1 The Maximum Gain: -1 KL Algorithm Stops

Final Cut Cost: 135

The program for circuit no. 1 completes within 0.415 seconds.

For the second circuit,

The number of edges: 472

The number of nodes: 181

Initial Cut Cost: 366

Main Pass Number	**Relative Statistics**
1	Number of Steps: 36 The Maximum Gain: 133 Current Cut Cost: 49 KL Algorithm Continues
2	Number of Steps: 5 The Maximum Gain: 13 Current Cut Cost: 25 KL Algorithm Continues
3	Number of Steps: 1 The Maximum Gain: 1 Current Cut Cost: 23 KL Algorithm Continues
4	Number of Steps: 1 The Maximum Gain: -1 KL Algorithm Stops

Final Cut Cost: 23

The program for circuit no. 2 completes within 0.626 seconds.

For the third circuit,

The number of edges: 800

The number of nodes: 191

Initial Cut Cost: 752

Main Pass Number	**Relative Statistics**
1	Number of Steps: 40 The Maximum Gain: 268 Current Cut Cost: 189 KL Algorithm Continues
2	Number of Steps: 10 The Maximum Gain: 32 Current Cut Cost: 124 KL Algorithm Continues
3	Number of Steps: 1 The Maximum Gain: 2 Current Cut Cost: 120 KL Algorithm Continues
4	Number of Steps: 1 The Maximum Gain: 0 KL Algorithm Stops

Final Cut Cost: 120

The program for circuit no. 1 completes within 0.789 seconds.

For the fourth circuit,

The number of edges: 947

The number of nodes: 195

Initial Cut Cost: 816

Main Pass Number	**Relative Statistics**
1	Number of Steps: 37 The Maximum Gain: 354 Current Cut Cost: 118 KL Algorithm Continues
2	Number of Steps: 7 The Maximum Gain: 7 Current Cut Cost: 98 KL Algorithm Continues
3	Number of Steps: 1 The Maximum Gain: 1 Current Cut Cost: 90 KL Algorithm Continues
4	Number of Steps: 1 The Maximum Gain: 0 KL Algorithm Stops

Final Cut Cost: 90

The program for circuit no. 4 completes within 0.827 seconds.

For the fifth circuit,

The number of edges: 791

The number of nodes: 201

Initial Cut Cost: 771

Main Pass Number	**Relative Statistics**
1	Number of Steps: 40 The Maximum Gain: 287 Current Cut Cost: 116 KL Algorithm Continues
2	Number of Steps: 10 The Maximum Gain: 6 Current Cut Cost: 103 KL Algorithm Continues
3	Number of Steps: 1 The Maximum Gain: 1 Current Cut Cost: 91 KL Algorithm Continues
4	Number of Steps: 1 The Maximum Gain: 0 KL Algorithm Stops

Final Cut Cost: 91

The program for circuit no. 5 completes within 0.986 seconds.

Reference:

[1] B. W. Kernighan and S. Lin, "An Efficient Heuristic Procedure for Partitioning Graphs", *Bell System Technical Journal*, September 30, 1969.

[2] Dr. Khalid**, "**Lecturer 3: Partitioning PDF File from Physical Design Automation for VLSI & FPGAs Course", Dept. of ECE, University of Windsor.