2006 Paper 5 Question 1

Data Structures and Algorithms

Dijkstra developed an efficient algorithm to find shortest paths on a directed graph from a designated source vertex to all other vertices, but only on graphs with non-negative edge weights.

(*a*) Give a clear and complete explanation of the algorithm. Be sure to cover its use of *relaxation* and to explain what happens if some vertices are not reachable from the source. [5 marks]

(*b*) Give a correctness proof for the algorithm. You may use the *convergence lemma* without having to prove it. [5 marks]

[Hint: here is the convergence lemma. **If** $s \rightsquigarrow u \to v$ is a shortest path from s to v, and at some time $d[u] = \delta(s, u)$, and at some time after that the edge (u, v) is relaxed, **then**, from then on, $d[v] = \delta(s, v)$.

Additional hint on notation: $s \rightsquigarrow u$ = path from s to u consisting of 0 or more edges (0 when $s \equiv u$); $u \to v$ = path from u to v consisting of precisely one edge; $d[u]$ = weight of the shortest path found so far from source s to vertex u; $\delta(s, v)$ = weight of shortest existing path from s to v.]

(*c*) Why does the algorithm require non-negative edge weights? [2 marks]

(*d*) Would the algorithm work if the only negative weights were on edges leaving the source? Justify your answer with a proof or counterexample. [5 marks]

(*e*) Consider the following approach for finding shortest paths in the presence of negative edges. "Make all the edge weights positive by adding a sufficiently large biasing constant to each; then find the shortest paths using Dijkstra's algorithm and recompute their weights on the original graph." Will this work? Justify your answer with a proof or counterexample. [3 marks]