

CS2010 PS6 - Caesarean Section

Released: Thursday, 13 October 2011

Due: Saturday, 22 October 2011, 8am

Collaboration Policy. You are encouraged to work with other students on solving this problem set. However, you **must** write up your solution **by yourself**. In addition, when you write up your solution, you **must** list the names of every collaborator, that is, every other person that you talked to about the problem (even if you only discussed it briefly). Any deviation from this policy will be considered cheating, and will be punished severely, including referral to the NUS Board of Discipline. It is not worth it to cheat just to get 15% when you will lose out in the other 85%.

The Story. This is a scenario that myself (Steven) and my wife (Grace) hope that we do *not* have to go through: a Caesarean section *surgery*. But whether Grace eventually has to go through this surgery procedure is not yet known (since Jane's birth is likely *after* this PS is released on Thursday, 13 October 2011).

Caesarean section is an *alternative* method of delivering a baby. It is a **surgical** procedure that involves the obstetrician (the doctor) '*cutting*' through the mother's abdomen, take out the baby, and *suture* the mother back to her original state. Sounds scary? You will probably think so after looking at this video: <http://video.about.com/pregnancy/Cesarean-Section.htm>.

In Singapore, most obstetrician will by default choose *normal delivery*. Only if there are *known complications* prior to the delivery (e.g. the baby is in breech position, etc) or *unexpected complications* during the attempted normal delivery (e.g. fetal distress, umbilical cord prolapse, etc), then the obstetrician may offer to perform this alternative delivery method.

As Caesarean section is a surgical procedure, it must be performed '*as fast as possible*' (you do not want the mother bleeds to death or the baby dies). However, it has step-by-step procedures that must be performed one after another (e.g. you have to put the mother on anaesthetic first before cutting her – you really do not want to reverse these two steps, etc). Each step has an estimated completion time. Sometimes, nurses, midwives, and/or paediatrician (child doctor) can help do some steps so that the overall surgery time can be minimized to reduce the father's anxiety.

For example, suppose an *over-simplified* Caesarean Section surgery is as follow:

(10 mins)	(15 mins)	(3 mins)	(30 mins)	(0 min)
Step 0 ---->	Step 1 --->	Step 2 ----->	Step 3 ----->	Step 6
Father see	Doctor	Doctor \	Doctor	-> Present the
that the	cut the	takes out \	sutures	/ mother AND
mother is	mother	the baby \	the mother	/ baby (both
put on	at the	carefully \		/ alive) to
anaesthetic	correct	(head first) \	(10 mins)	(5 mins) / the father
and the	spot(s)	->	Step 4 --->	Step 5--/
baby is			Nurse	Paediatrician measures
still in			cleans	the baby's
the womb			the baby	birth parameters

In the example above, the start of the surgery is step 0, when the father saw the baby is still *inside* the mother's womb and the mother is put on anaesthetic. The end of the surgery is step 6 when the father saw the living baby *outside* the womb **and** he also saw his wife alive. Here, the father has to wait anxiously for $10+15+3+30 = 58$ minutes to get **both** good news.

The Actual Problem. Given a dependency information between various steps of a Caesarean section surgery (as a directed graph that will not have a cycle), estimated time perform such steps (as weights of the corresponding vertices – in minutes), determine the *quickest time* to complete the whole Caesarean section surgery, i.e. from the first step 0 (the mother is put on anaesthetic) until the last step $V-1$ (the father sees both the mother and the baby alive) can be completed.

Each step can only be performed by one person (usually the doctor). However, if there are two (or more) steps that can be performed by another qualified persons (another doctor, nurse, midwife, paediatrician, even the father, etc), the doctor *can always* call for enough number of helpers to speed up the process while the doctor is taking care on one other step.

The skeleton program `Caesarean.java` is already written for you, you just need to implement one (or more) method(s)/function(s):

- `int Query()`

You are given an (unweighted) Edge List data structure¹ **EL** that stores the dependency information between various V steps of a Caesarean section surgery. An edge (u, v) in **EL** implies that step u must be performed *before* step v . You can assume that there is always a sequence of steps from step 0 that ends up at step $V-1$. You are also given an array **estT** of size V that stores the estimated time to complete each step (step $V-1$ always has 0 minute). Query these two data structures and answer the query as defined above.

- If needed, you can write additional helper methods/functions to simplify your code.

Subtask 1 (50 points). In this subtask, the obstetrician already plan the sequence of steps very carefully so that by executing step 0, 1, 2, ..., $V-1$, in that order, he/she will be able to complete the surgery successfully without violating any step dependency². The sample shown above fits this description. Constraints: $1 \leq V, E \leq 10$.

Subtask 2 (30 points). In this subtask, the obstetrician has *not* plan the sequence of steps yet. You have to help him/her plan the surgical steps (so that he/she can ask enough number of other person to help performing some of the steps). Constraints: $1 \leq V, E \leq 10$.

Subtask 3 (25 points). Same as Subtask 2, but $1 \leq V, E \leq 200000$. As the test data is a bit large, you have to come up with the *most efficient* solution that you can think of.

Note 1: The test data to reach 50 points: `Subtask1.txt` and `Subtask1-ans.txt` are given to you. You are allowed to check your program's output with your friend's.

Note 2: If you total the marks, you will see that you can either get $50+30 = 80$ marks for a correct but 'slow' solution or 105 marks for a correct and 'fast' solution.

¹Already implemented in `Caesarean.java`.

²Violation of this step dependency can harm the mother or the baby.