CSE647: Robust (Distributed) Software (Spring 2002)
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Homework 2. Due: 26 Feb

As always, justify your answers. For each part of each problem, a few well-chosen sentences is sufficient justification. You may write more if you like.

Classic Paxos

1. In $Start_v^p$ on p. 10, suppose we delete the assignment $c^p := nil$. Is CP still safe (i.e., is it still a refinement of AP)?
Answer: Probably not. This change would allow a primary to re-use in a new view v_3 the value of c^p from a previous view v_1, instead of calculating it afresh. Another primary may have led an intermediate view v_2 using a different choice. If v_2 is not visibly out, then v_3 should be consistent with v_2 (i.e., make the same choice). Note that v_2 could make a different choice than v_1, if v_1 is visibly out.

2. Describe how a primary evaluates an expression like $(Q_{dec}[r_v^* = x])@p$. (This expression occurs in the definition of re_v^p on p. 10.) Mention the necessary communication as well as the necessary local computations. (This question just checks your understanding of the operational intentions underlying the abstract description of the algorithm.)
Answer: The primary keeps track of messages it received containing values of r_v^a, and checks whether it has received messages with $r_v^a = x$ from a Q_{dec} quorum of agents a.

Byzantine Paxos (without Digital Signatures)

3. Explain why $anchor_u$, as opposed to $anchor_u^a$, is used in (B5) on p. 12.
Answer: This is necessary for liveness. $anchor_u^a$ might be "unknown" (i.e., not determined by (B5)) if (e.g.) a does not receive enough messages to conclude $out_{u_1,u}^a$. But a can later receive messages from a $Q_{\neg F}^+$ quorum showing $x \in anchor_u$.

4. Describe how an agent checks $x \in anchor_u$, which, by equation (B5), is needed to check whether $x \in anchor_v^a$, which is needed to evaluate the guard of $Choose_v^a$. Note that an agent does not need to compute the entire set $anchor_u$.
Answer: An agent concludes $x \in anchor_u$ if it receives messages stating $x \in anchor_u^a$ from every agent a in some $Q_{\neg F}^+$ quorum. (It seems to me that a $Q_{\neg F}$ quorum would suffice.)

Notes

1. Regarding the invariant on p. 10, col. 1, line 13, I don't see how $active^p$ could ever be nil. I expected this invariant to be $active^p \Rightarrow active_{v^p}$.

2. In the "table" on p. 10, col. 1, line -16 (i.e., 16th from the bottom), I suspect that $re_{v^p}^p \notin X$ should be $re_{v^p}^p \neq nil$ (*cf.* the guard of $Accept^p$ in Section 7.1).

3. I don't understand the expressions $c_v@a$ and $re_v^p@a$ on p. 10, col. 2, line 2, because c_v and re_v^p are not predicates. I expected these expressions to be something like c^{p_v} and $re_v^{p_v}$, respectively. Lampson's intentions come across better in the definitions of $Accept^p$ and $Finish^p$ in Section 7.1.

4. In Section 8.3, in the paragraph starting with "Now we consider", I think "$x \in anchor_u^a$" should be "$(x \in anchor_u)@a$".

5. In the definition of $Choose_v^a$ in Section 8.1, the open parenthesis should be before "x" not before "$c_v^{p_v}$".