

**HW for 2019-06-14**

(due: 2019-06-24)

**1: PageRank bounds** Show that the PageRank of any node  $i$  is at least  $[\alpha\pi_{\text{ref}}]_i$ .

**2: Katz with more edges** Argue that adding an edge to a graph increases the Katz centrality of all nodes.

**3: Estrada on average** For a symmetric matrix  $A = Q\Lambda Q^T$ , the matrix exponential is

$$\exp(A) = Q \exp(\Lambda) Q^T.$$

Use this formula to write the Estrada centrality of a node as the weighted average of exponentials of eigenvalues of  $A$ .