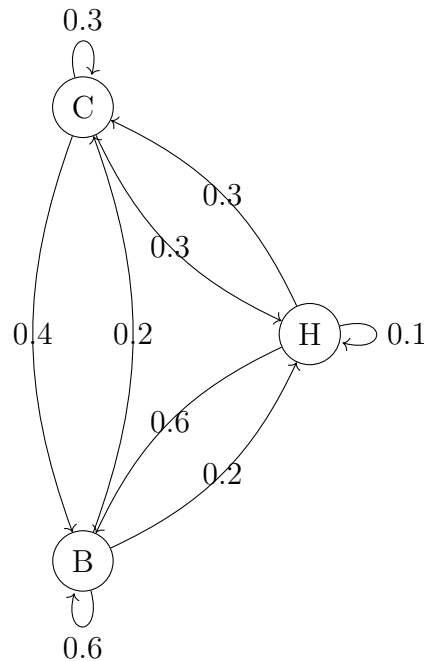


**Exercise 1****(a)**

Transition matrix with row order (top to bottom) and column order (left to right)  $H - B - C$ :

$$Q := \begin{bmatrix} 0.1 & 0.6 & 0.3 \\ 0.2 & 0.6 & 0.2 \\ 0.3 & 0.4 & 0.3 \end{bmatrix}$$

**(b)**

$$\begin{aligned} \sum_{a \in H, C, B} q_{Ha} \cdot q_{aB} &= q_{HH} \cdot q_{HB} + q_{HB} \cdot q_{BB} + q_{HC} \cdot q_{CB} \\ &= 0.1 \cdot 0.6 + 0.6 \cdot 0.6 + 0.3 \cdot 0.4 \\ &= 0.06 + 0.36 + 0.12 \\ &= 0.54 \end{aligned}$$

**(c)**

We have the following equations (also since  $\pi$  is a left Eigenvector of  $Q$  with Eigenvalue 1):

$$\pi_1 + \pi_2 + \pi_3 = 1 \tag{1}$$

$$\pi \cdot Q = \pi \tag{2}$$

Thus, we have the following equation system:

$$\begin{aligned} \pi_1 + \pi_2 + \pi_3 &= 1 \\ 0.1 \cdot \pi_1 + 0.2 \cdot \pi_2 + 0.3 \cdot \pi_3 &= \pi_1 \\ 0.6 \cdot \pi_1 + 0.6 \cdot \pi_2 + 0.4 \cdot \pi_3 &= \pi_2 \\ 0.3 \cdot \pi_1 + 0.2 \cdot \pi_2 + 0.3 \cdot \pi_3 &= \pi_3 \end{aligned}$$

Solving this, we get:

$$\pi \simeq (0.204082, 0.55102, 0.244898)$$

## Exercise 2

(a)

(b)

## Exercise 3

SOLUTION IS WRONG

(a)

$$q_{ij}^{(n,r)} := \begin{cases} \frac{1-r}{2} + \frac{r}{n} & \text{if } i \in \{1, \dots, n-1\} \wedge (j = i+1 \vee j = n) \\ \frac{1}{n} & \text{if } i = n \\ \frac{r}{n} & \text{otherwise} \end{cases}$$

(b)

The Web graph is isometric "under rotation" around node  $n$ . Thus, the weight vectors for each  $i \in \{1, \dots, n-1\}$  must be equal. Let  $w_a$  denote the weight of each of these pages and  $w_n$  denote the weight of page  $n$ .

Similarly to Exercise 01.c), we get the following equation system:

$$\begin{aligned} (n-1) \cdot w_a + w_n &= 1 \\ (w_a + w_n) \cdot \left(\frac{1-r}{2} + \frac{r}{n}\right) + (n-2) \cdot w_a \cdot \left(\frac{r}{n}\right) &= w_a \\ (n-1) \cdot w_a &= w_n \end{aligned}$$

Thus:

$$\begin{aligned} w_n &= \frac{1}{2} \\ w_a &= \frac{1}{2(n-1)} \\ w_a &= \frac{r-1}{2(r+1)} \\ n &= \frac{2r}{r-1} \end{aligned}$$

## Exercise 4

(a)

MAP function:

- On input  $(R, t)$ , emit  $(t, 1)$ .

- On input  $(S, t)$ , emit  $(t, 1)$ .

REDUCE function:

- On input  $(t, values)$ , emit  $(Q, t) \sum_{v \in values} v$  times.

(b)

MAP function:

- On input  $(R, t)$ , emit  $(t, 1)$ .
- On input  $(S, t)$ , emit  $(t, 1)$ .

REDUCE function:

- On input  $(t, values)$ , emit  $(Q, t) \sum_{v \in values} v$  times, if  $t$  satisfies  $C$ .

## Exercise 5

(a)

MAP function:

- On input  $(o, (c, p, q, d))$ , emit  $(p, q)$ .

REDUCE function:

- On input  $(p, values)$ , emit  $(p, \sum_{q \in values} q)$ .

(b)

MAP function:

- On input  $(o, (c, p, q, d))$ , emit  $(c, (p, q))$ .

REDUCE function:

- On input  $(c, values)$ , emit  $(c, (p, q))$  for all  $(p, q) \in values$ , only if  $\forall_{(p,q) \in values} q < 20\$$ .

(c)

The algorithm is terrible, since, after Mapping all the data, we only have one  $(key, values)$ -pair left for the Reduction. Thus, we cannot distribute the computation of the REDUCE function.