

Constraint-based Modeling of Cellular Networks

Exercise 13 – EFM

26. 1. 2023

Identifying EFMs

- Find the maximal number of reactions that can have a 0 flux while the remaining active reactions still satisfy the steady state constrain

Identifying EFMs

Find the maximal number of reactions that can have a 0 flux while the remaining active reactions still satisfy the steady state constrain

Step 1: Split reversible reactions into two irreversible

Step 2: Introduce binary variable y_i for each reaction in the network such that

$$\text{If } y_i = 0 \Leftrightarrow v_i = 0$$

$$\text{If } y_i = 1 \Leftrightarrow \varepsilon \leq v_i \leq v_i^{max}$$

Next: Write the appropriate objective function

The LP

$$\min \sum y_i$$

s.t.

$$\begin{aligned} Nv &= 0 \\ v_i &\leq y_i v_i^{\max} \\ y_i \varepsilon &\leq v_i \\ y_i &\in \{0,1\} \end{aligned}$$

Next: Add a constraint that exclude trivial solution
(no reaction carrying flux)

The LP

$$\min \sum y_i$$

s.t.

$$\begin{aligned} Nv &= 0 \\ v_i &\leq y_i v_i^{\max} \\ y_i \varepsilon &\leq v_i \\ y_i &\in \{0,1\} \\ \sum y &\leq 1 \end{aligned}$$

Next: Enforce directionality of reverse reactions

The LP

$$\min \sum y_i$$

s.t.

$$Nv = 0$$

$$v_i \leq y_i v_i^{max}$$

$$y_i \varepsilon \leq v_i$$

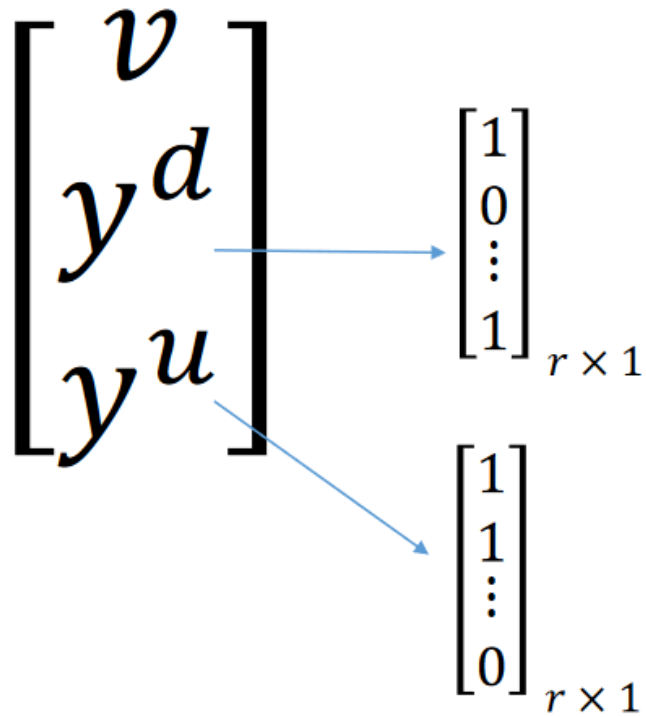
$$y_i \in \{0,1\}$$

$$\sum y \leq 1$$

For paired reactions R_j

$$y_{jFw} + y_{jBw} \leq 1$$

Alternative Solution – integer cut



(1) Find zeros from these two vectors (e.g. using `find(...)`)

For instance: $y_2^d = y_{12}^d = y_{25}^d = y_{51}^d = y_3^u = y_{10}^u = y_r^u = 0$

Take into account that there is integer tolerance options.`IntegerTolerance`

(2) Add an additional constraint:

$$y_2^d + y_{12}^d + y_{25}^d + y_{51}^d + y_3^u + y_{10}^u + y_r^u \geq 1$$

(at least one of them must be equal to one)

How to modify if $y_i = 1$ means that a reaction is in the previous solution?