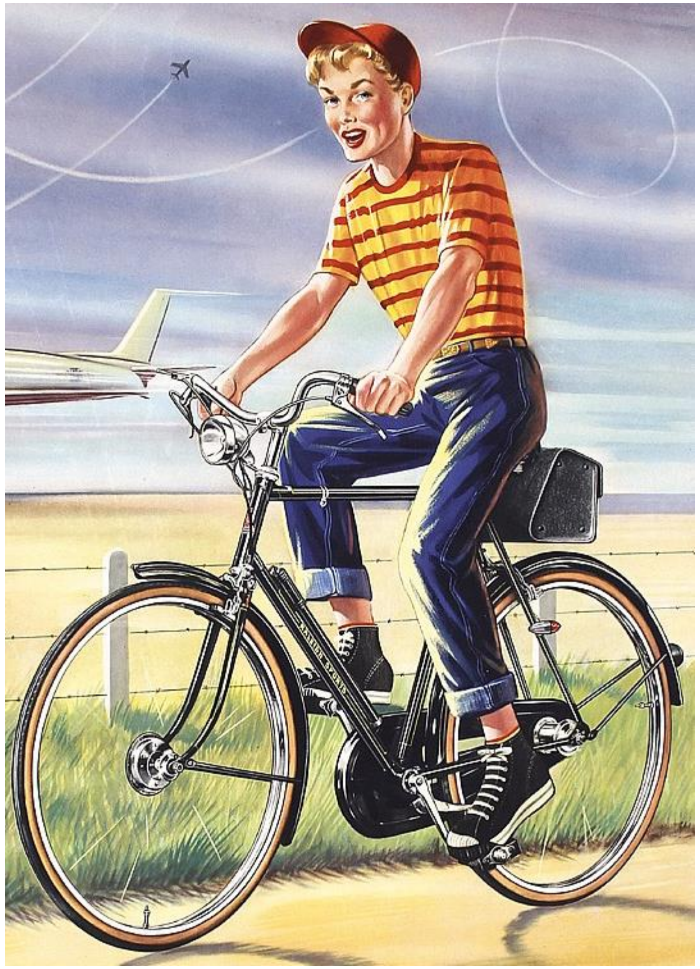
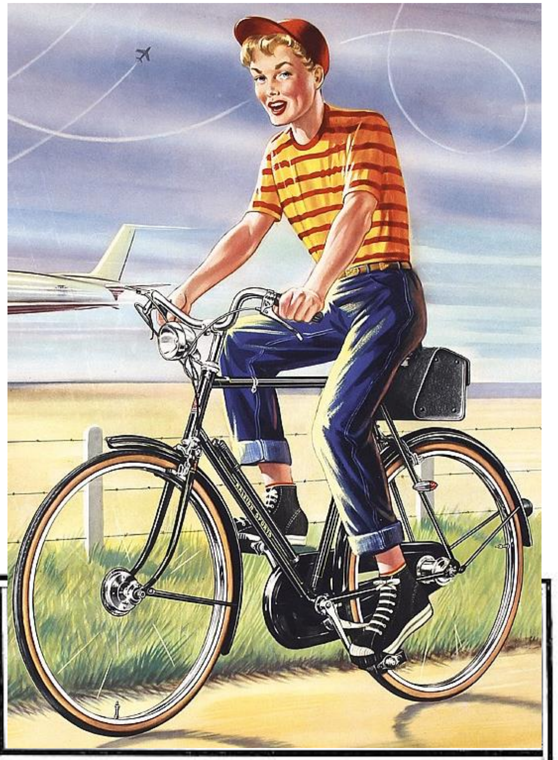
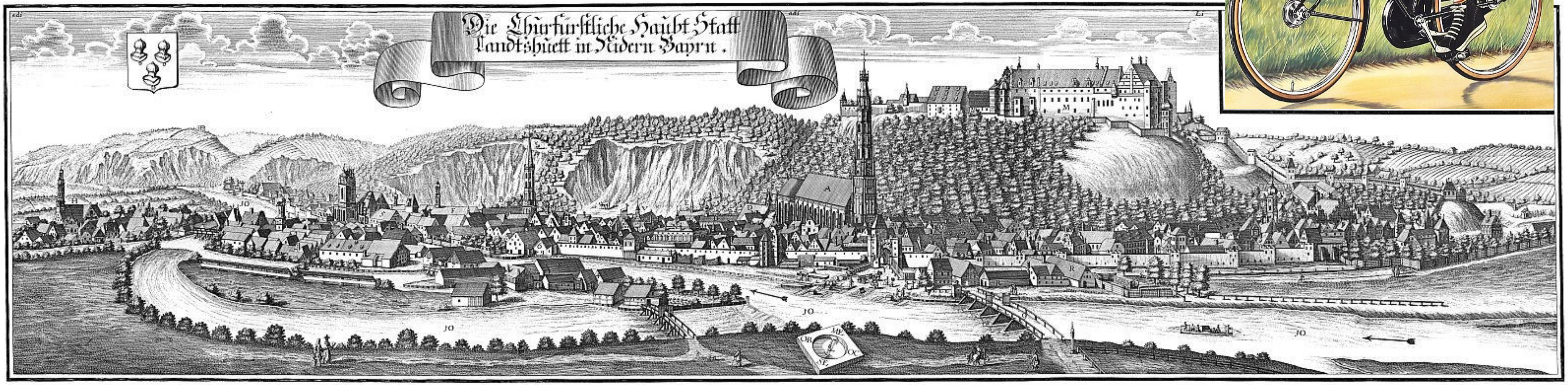
Amöben als Problemlöser



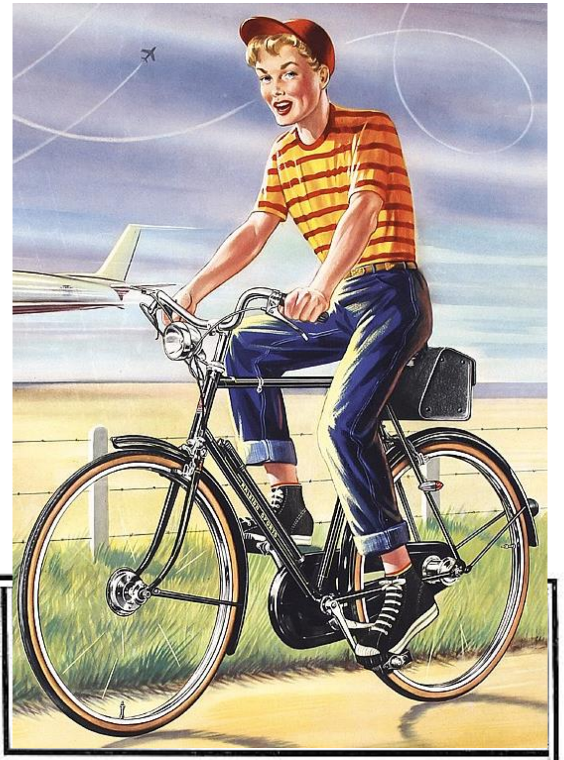
Tobias Weiden
Student Master Informatik
HAW Landshut

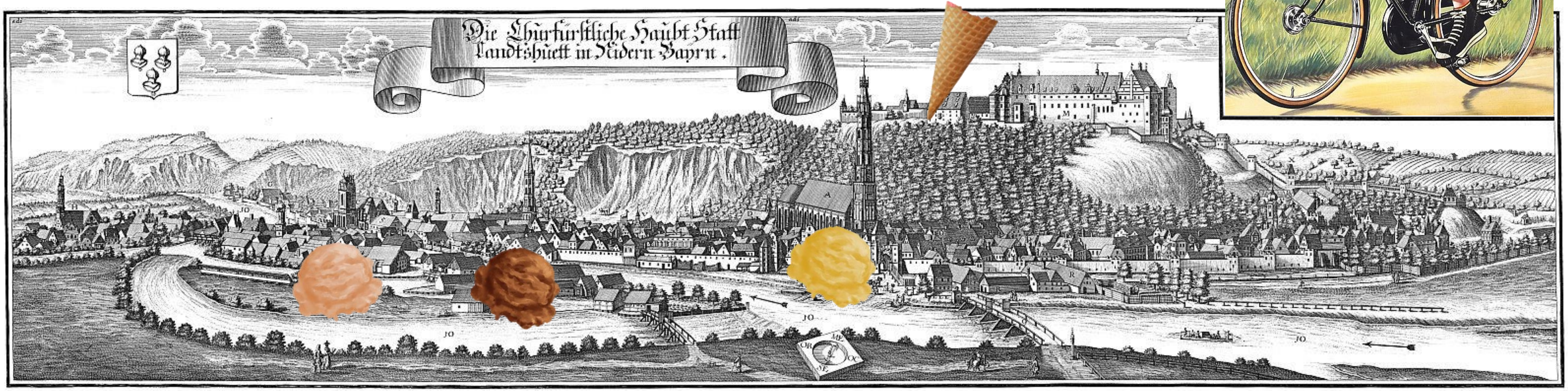
Das Sommerdilemma





Das Sommerdilemma

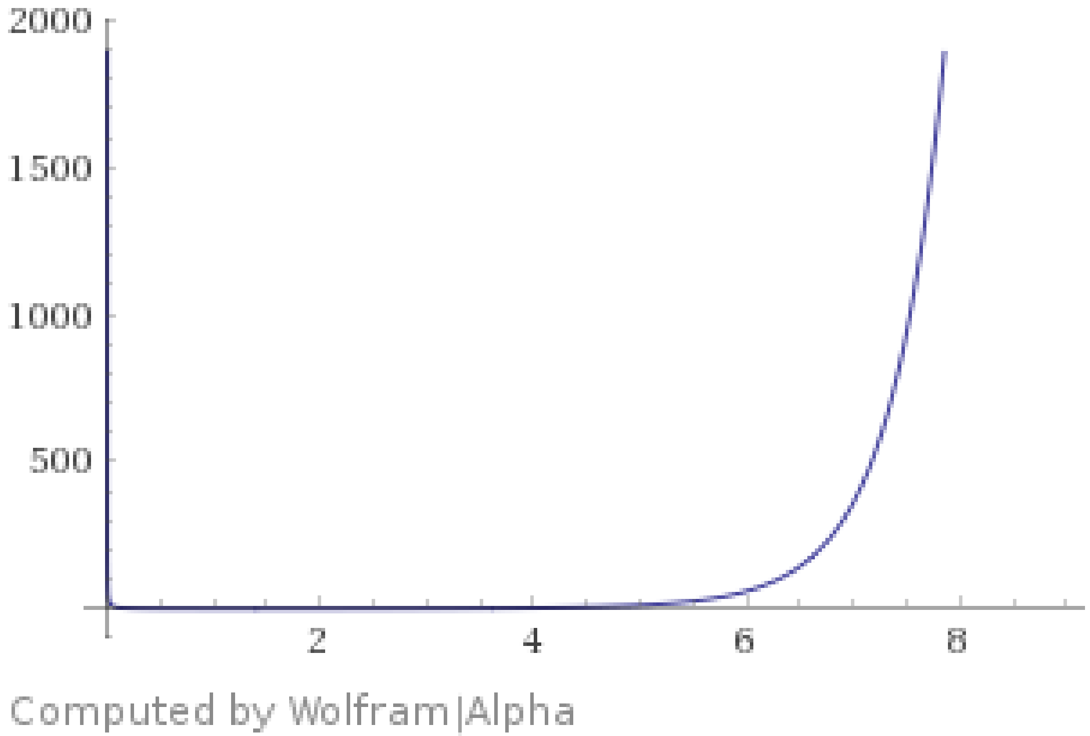




Das Sommerdilemma

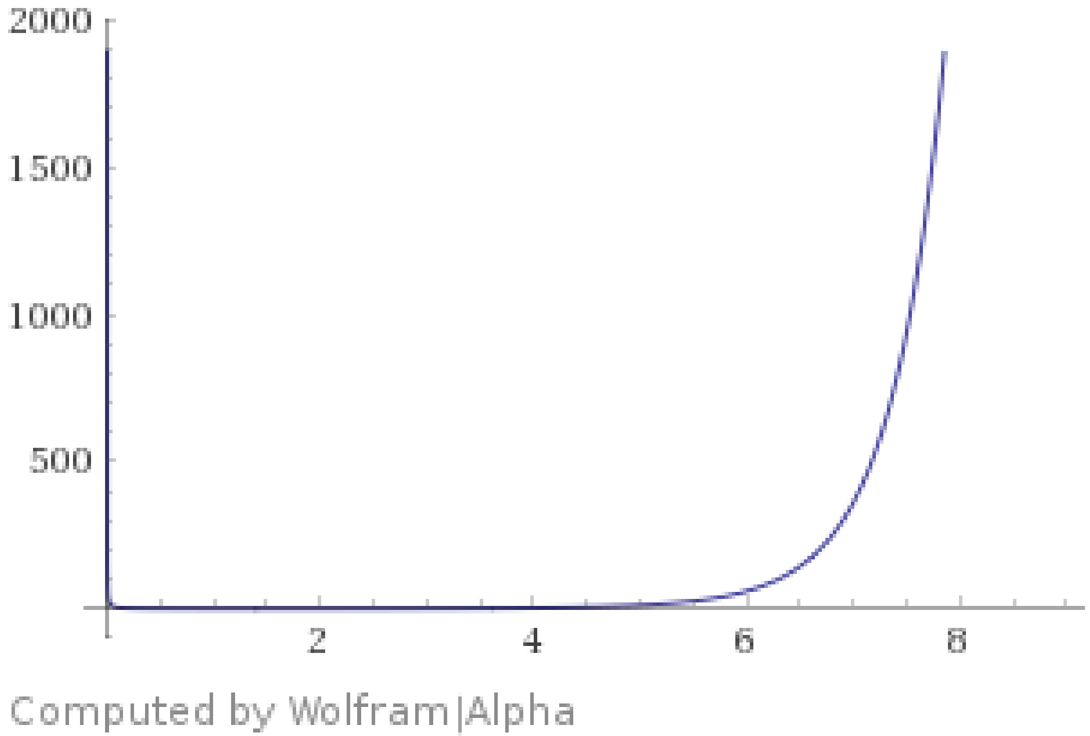
Erlaubte Touren: $(n-1)!/2$

Das Sommerdilemma



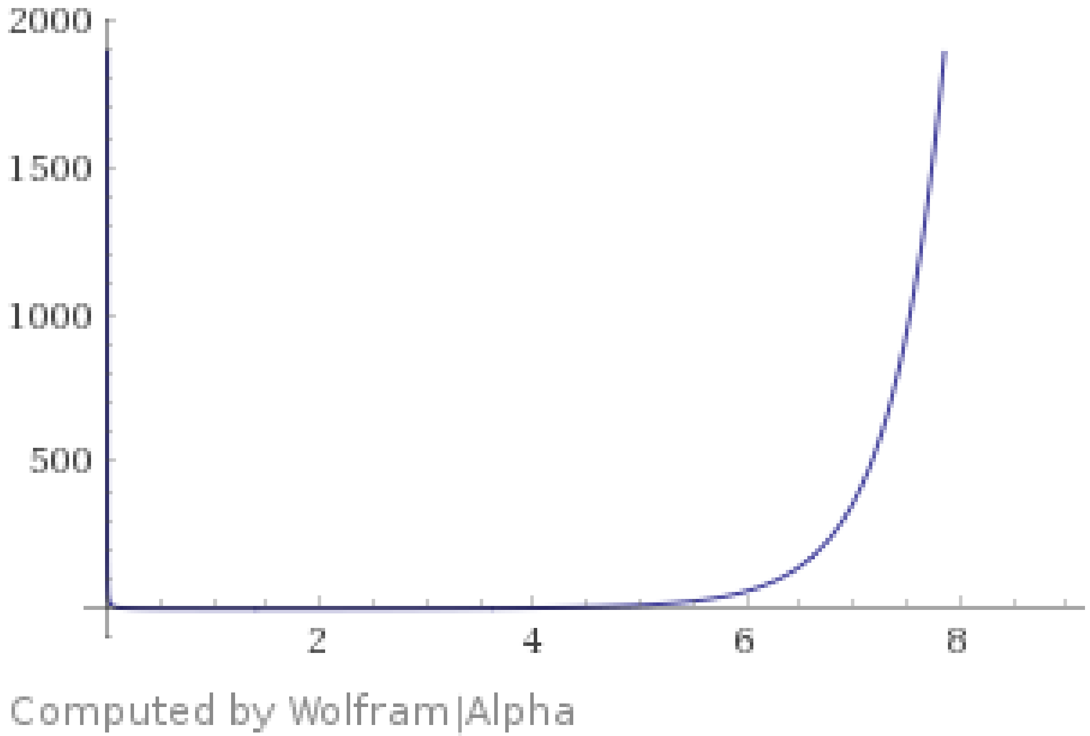
Erlaubte Touren: $(n-1)!/2$

Travelling Salesman Problem



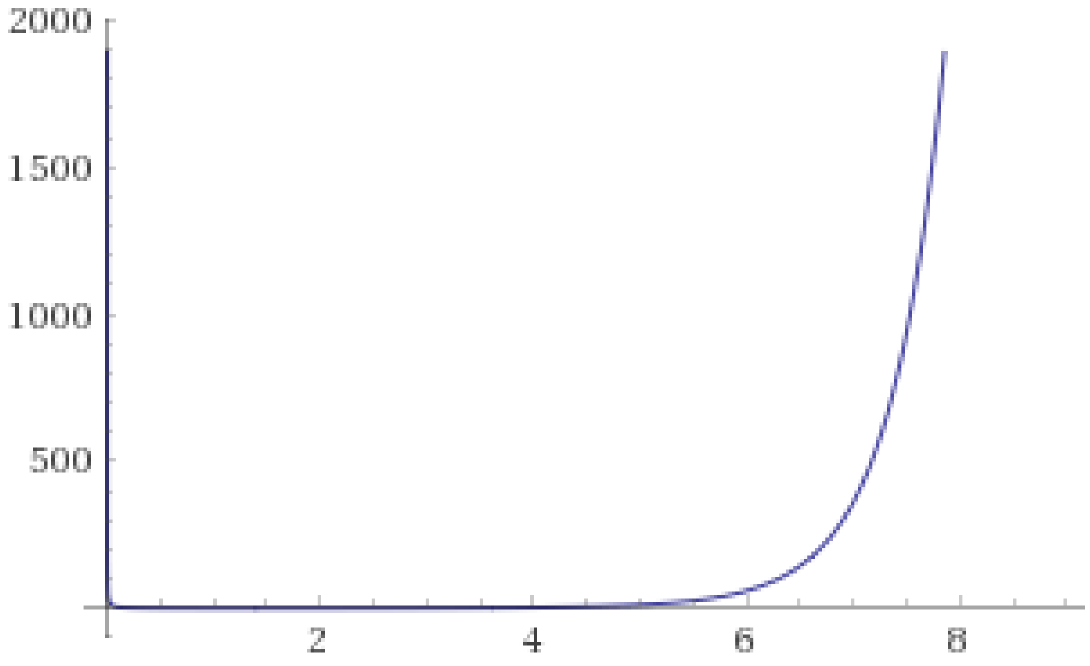
Erlaubte Touren: $(n-1)!/2$

Travelling Salesman Problem



- Erlaubte Routen: $(n-1)!/2$
- NP-Schweres Problem
- Suchzeit für optimale Route:

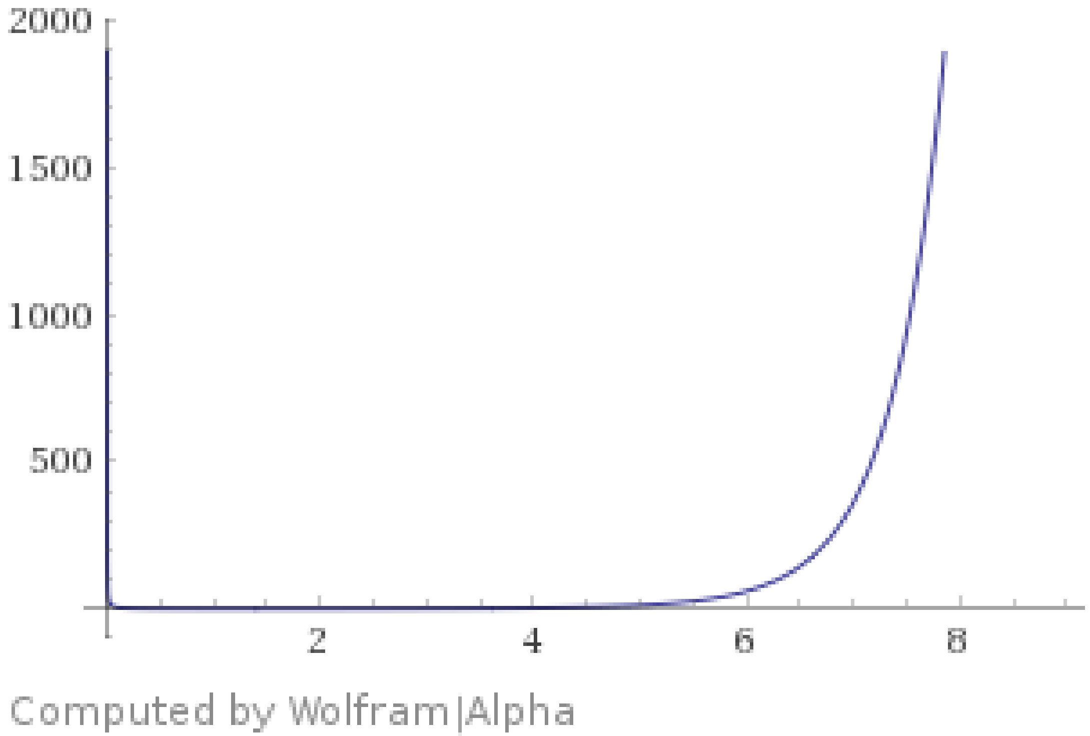
Travelling Salesman Problem



Computed by Wolfram|Alpha

- Erlaubte Routen: $(n-1)!/2$
- NP-Schweres Problem
- Suchzeit für optimale Route: $O(n^2)$

Das Sommerdilemma



- Erlaubte Routen: $(n-1)!/2$
- NP-Schweres Problem
- ~~Suchzeit für optimale Route:~~ $\cancel{O(n^2)}$
- Gute Route zu annehmbarer Zeit

Das Thema

Remarkable problem-solving ability of unicellular amoeboid organism and its mechanism

By Liping Zhu, Song-Ju Kim, Masahiko Hara and Masashi Aono

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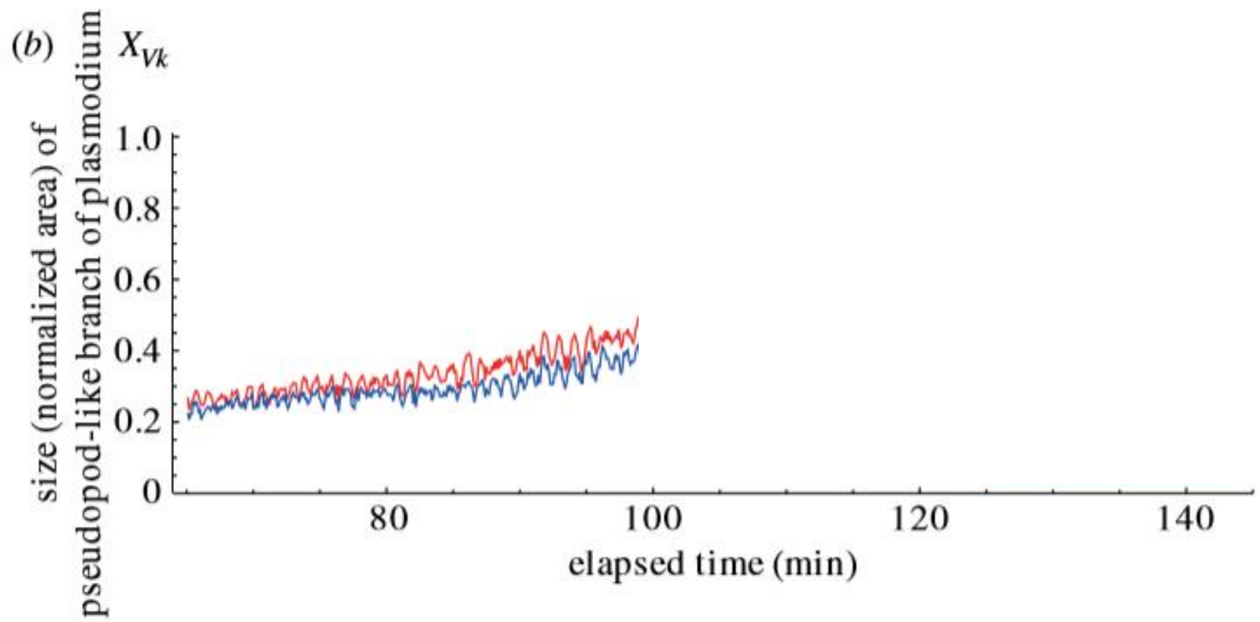
Amöben – Kluge Hilfe

Amöben – Kluge Hilfe

Physarum polycephalum

- Gruppe von Einzellern
- Gut erforscht
- Licht-avers

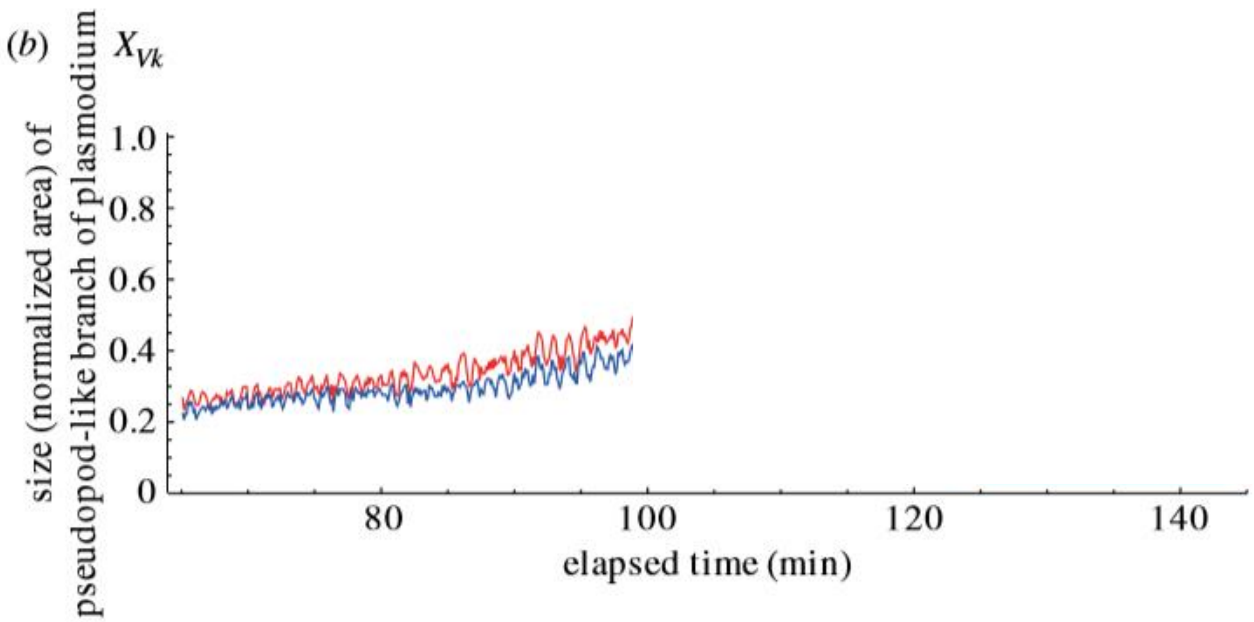
Amöben – Kluge Hilfe



Physarum polycephalum

- Wächst Wellenförmig (Oszillation)

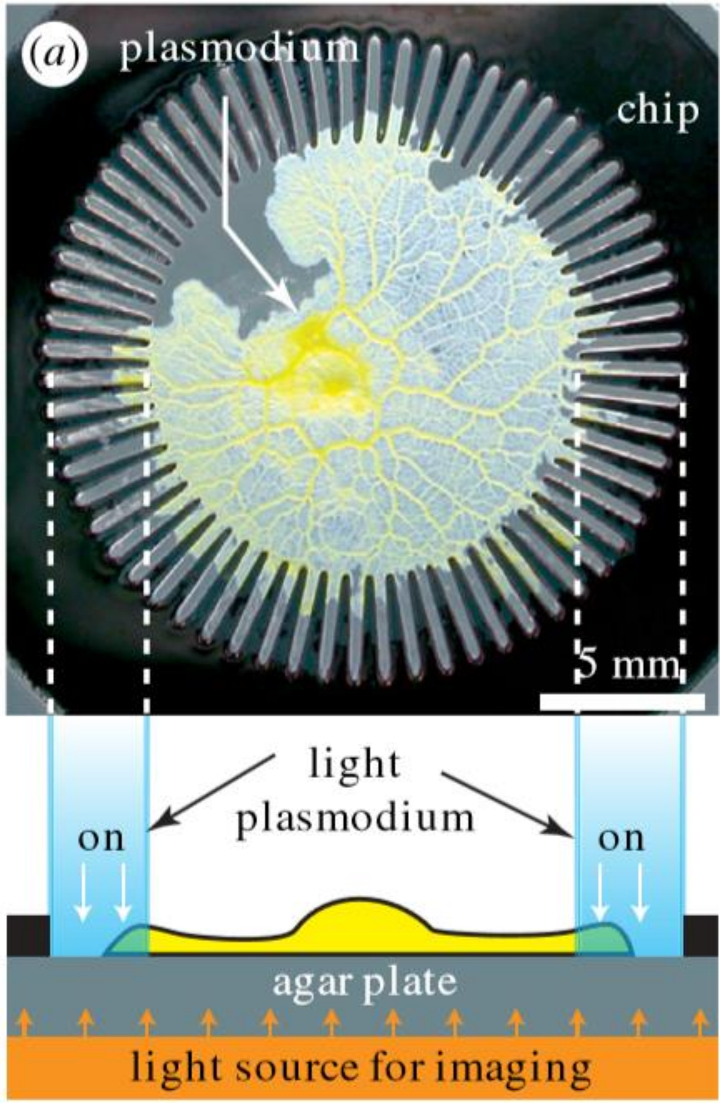
Amöben – Kluge Hilfe

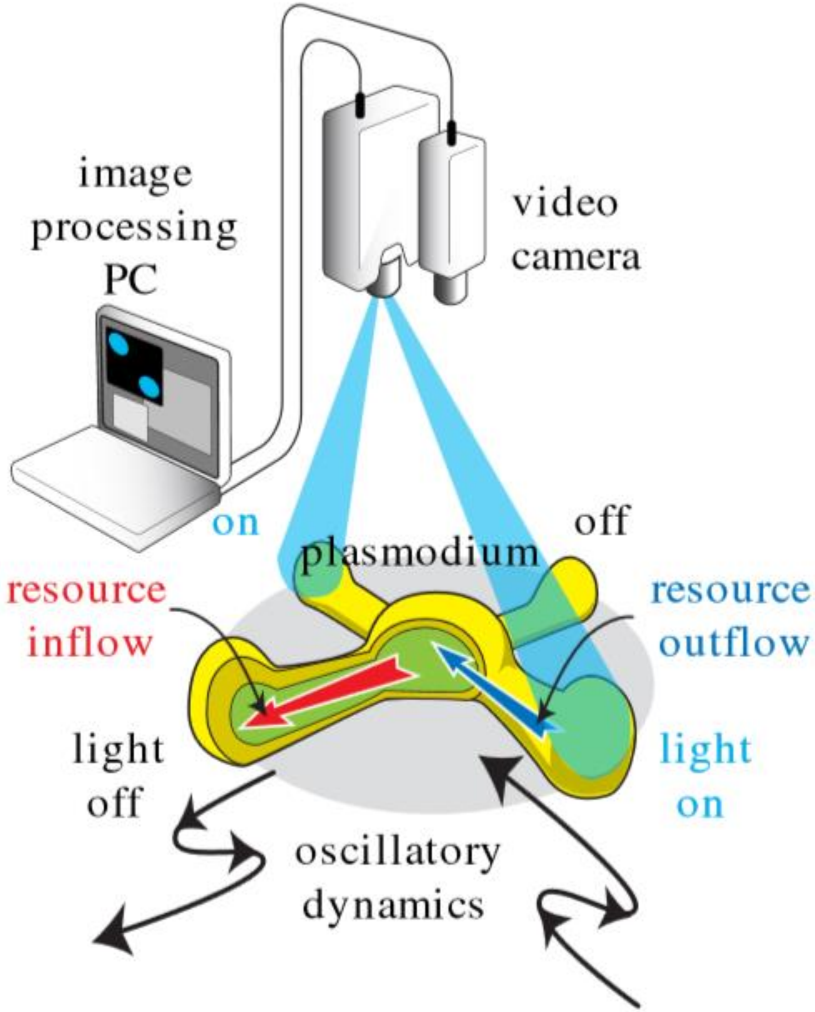


Physarum polycephalum

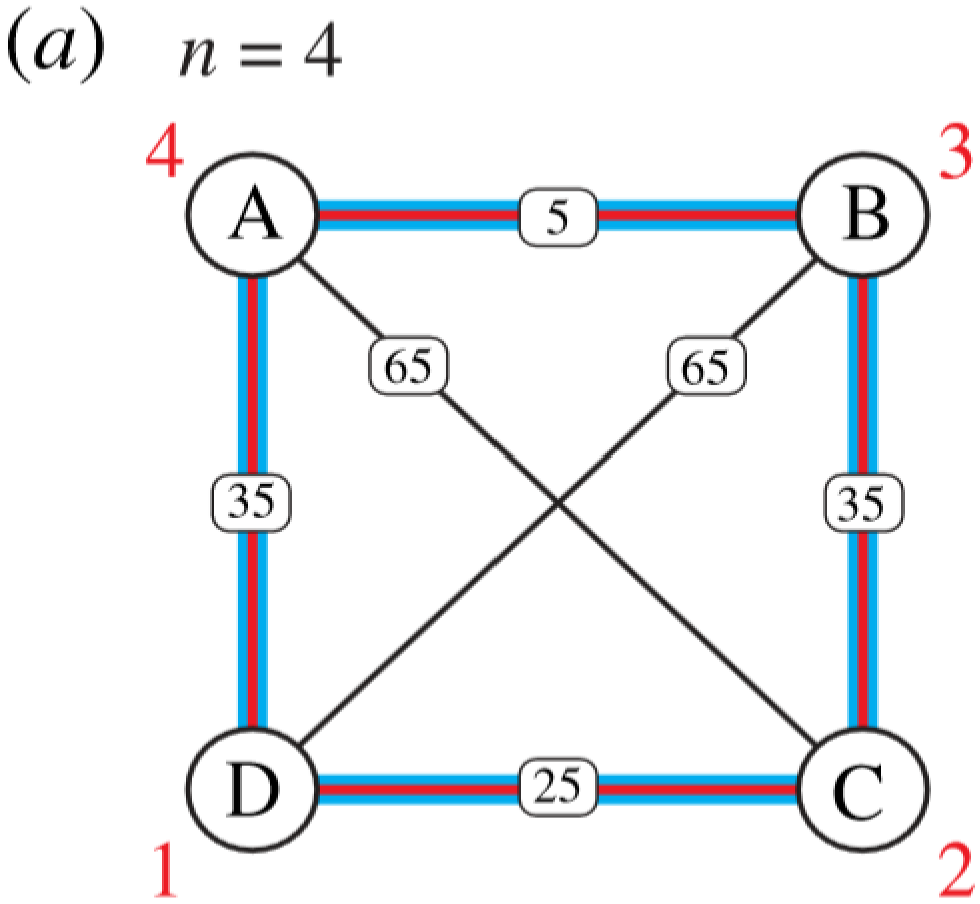
- Wächst Wellenförmig (Oszillation)

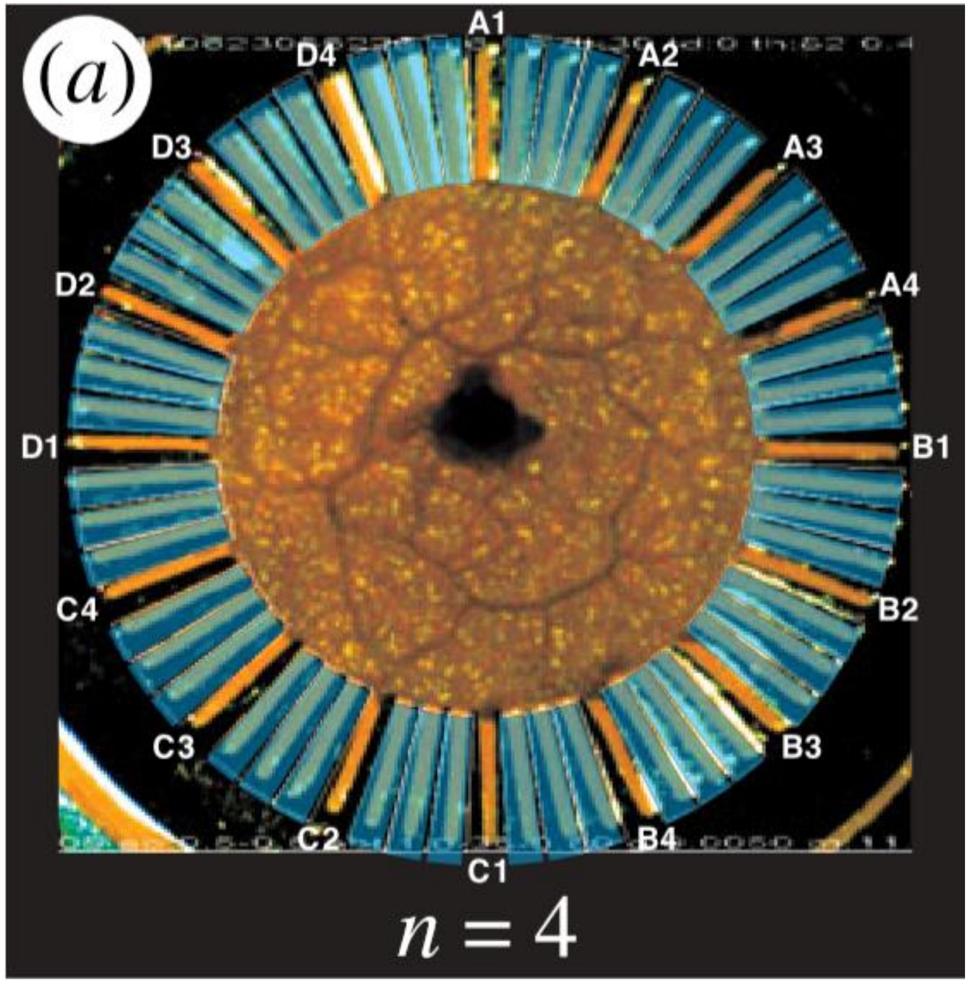
Versuchsaufbau



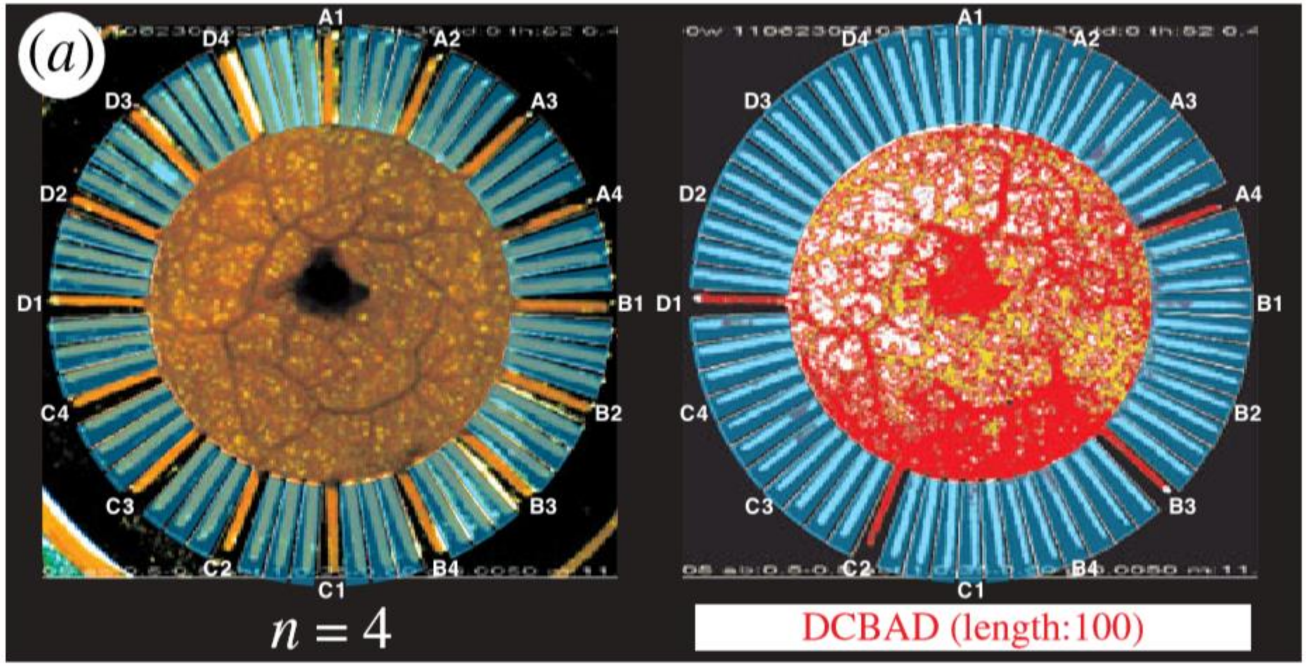


Versuchsaufbau





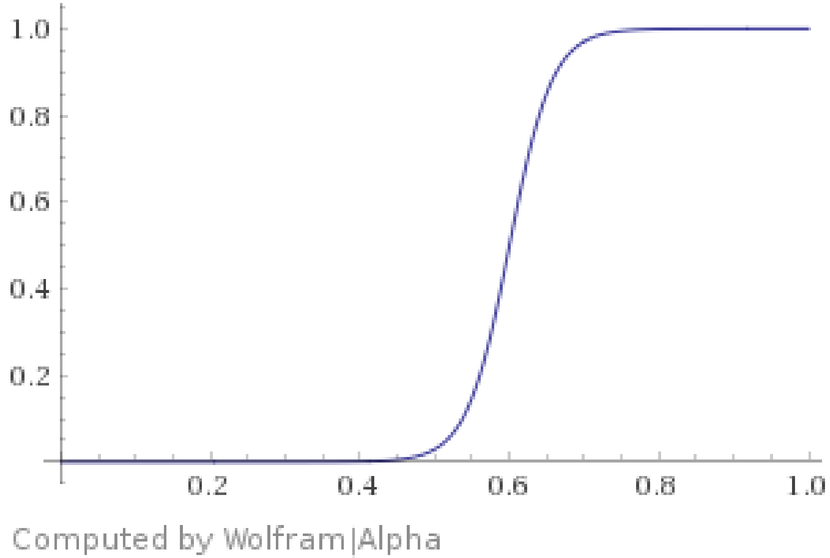
$$L_{Vk}(t+\Delta t) = 1 - \sigma_{1000,-0.5}\left(\sum_{Ul} W_{Vk,Ul} * \sigma_{35,0.6}\left(X_{Ul}(t)\right)\right)$$



Status $X_{Vk}(t) \in [0.0, 1.0]$:

Abdeckung Der Linie Vk durch Amöbe

$$L_{Vk}(t+\Delta t) = 1 - \sigma_{1000,-0.5}\left(\sum_{Ul} W_{Vk,Ul} * \sigma_{35,0.6}\left(X_{Ul}(t)\right)\right)$$



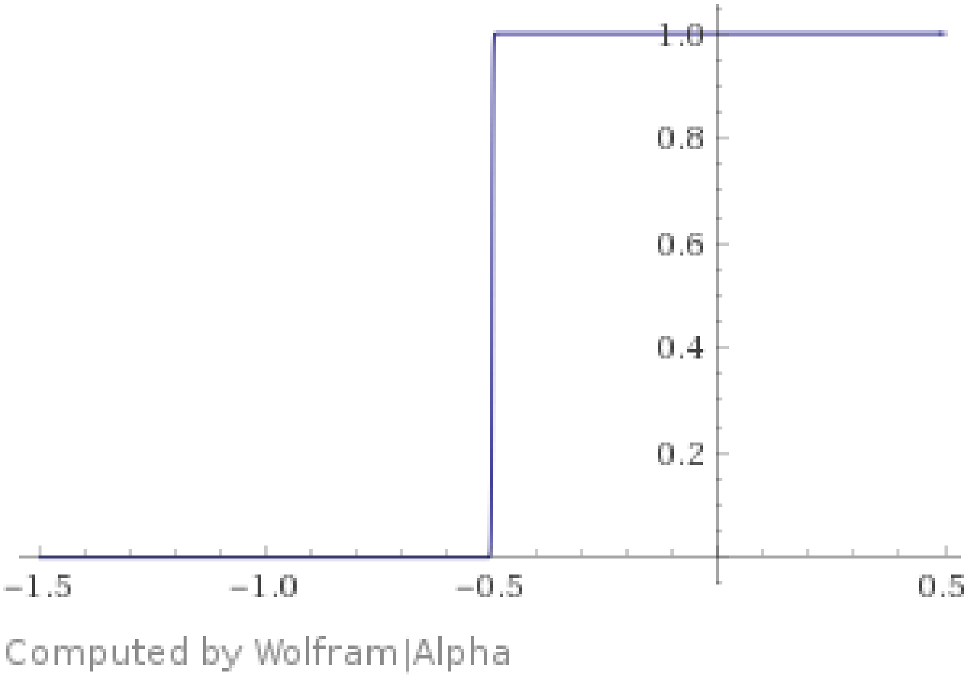
$$\sigma_{\gamma,\theta} = 1/(1 + \exp(-\underbrace{\gamma}_{35} * (x - \underbrace{\theta}_{0.6})))$$

→ Sobald die Hälfte der Linie belegt ist steigt der Wert gegen 1

$$L_{Vk}(t+\Delta t) = 1 - \sigma_{1000,-0.5}\left(\sum_{Ul} W_{Vk,Ul} * \sigma_{35,0.6}\big(X_{Ul}(t)\big)\right)$$

$$W_{Vk,Ul} \begin{cases} -0.5 & \text{Wenn } V = U \text{ und } k \neq l \\ -0.5 & \text{Wenn } V \neq U \text{ und } k = l \\ -v * dist(V,U) & \text{Wenn } V \neq U \text{ und } |k-l| = 1 \\ 0 & \text{Ansonsten} \end{cases}$$

$$L_{Vk}(t+\Delta t) = 1 - \sigma_{1000,-0.5}\underbrace{\left(\sum_{Ul} W_{Vk,Ul} * \sigma_{35,0.6}\big(X_{Ul}(t)\big)\right)}_{x}$$



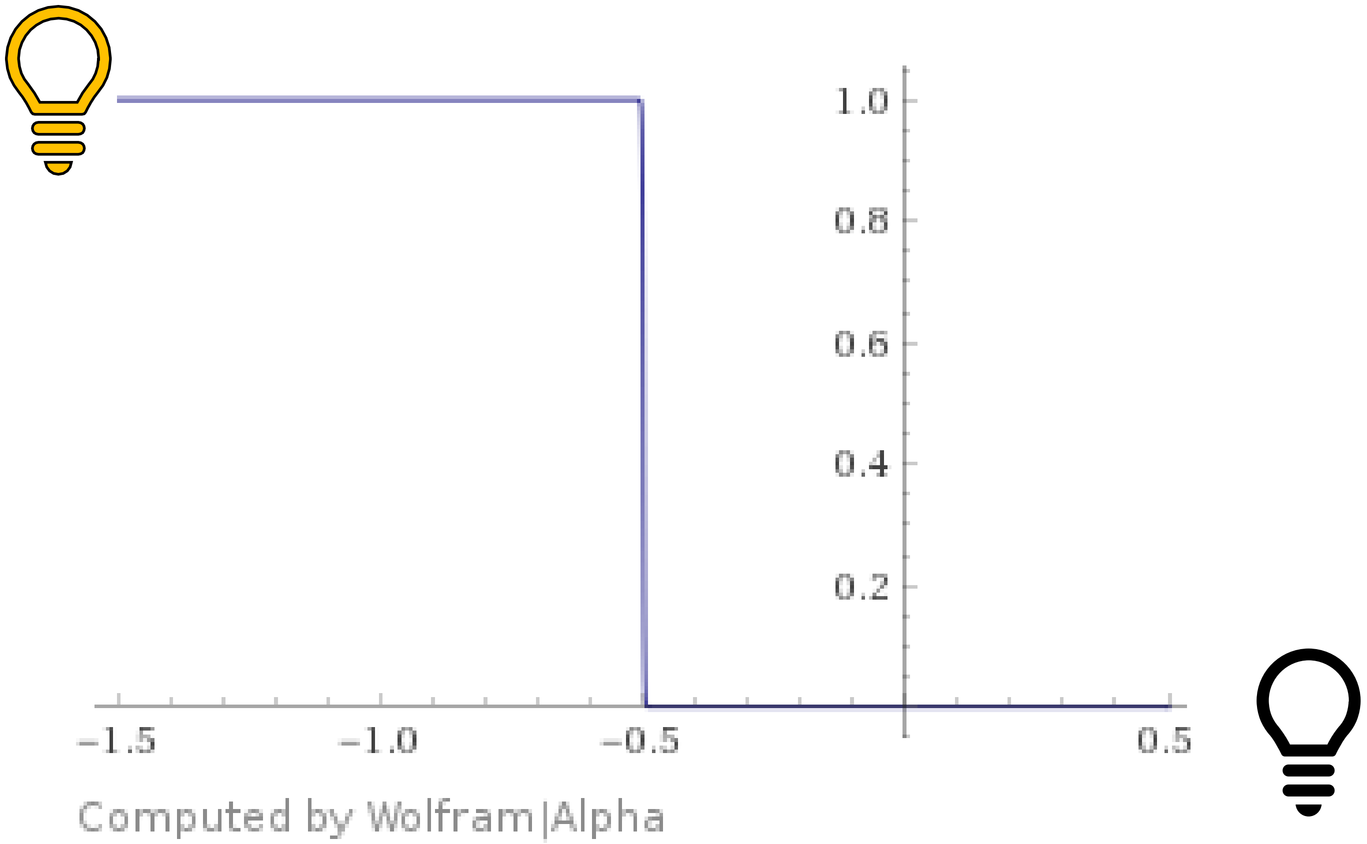
1000 -0.5

$$\sigma_{\gamma,\theta} = 1/(1+\exp(-\gamma * (x-\theta)))$$

Nachbar oder Gegenüber belegt

➢ $L = 0.5$

$$L_{Vk}(t+\Delta t) = 1 - \sigma_{1000,-0.5}\underbrace{\left(\sum_{Ul} W_{Vk,Ul} * \sigma_{35,0.6}\left(X_{Ul}(t)\right)\right)}_{x}$$

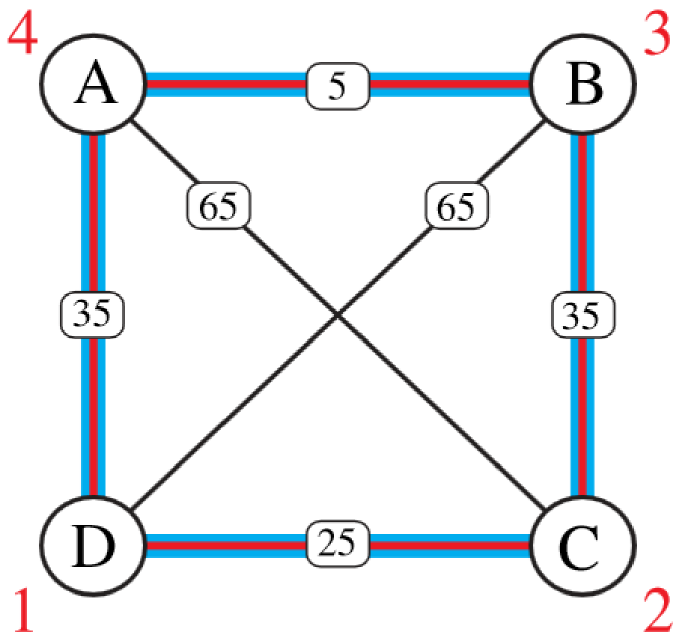


Nachbar oder Gegenüber belegt

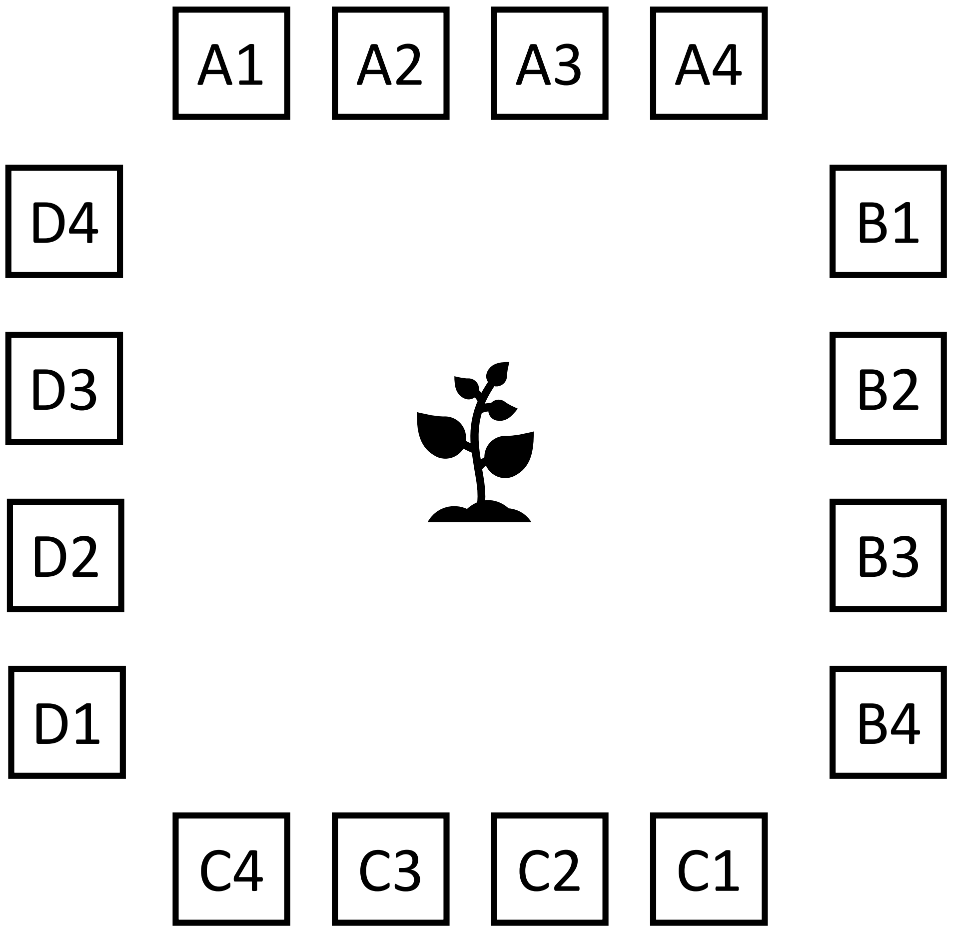
Nachbar und Gegenüber frei

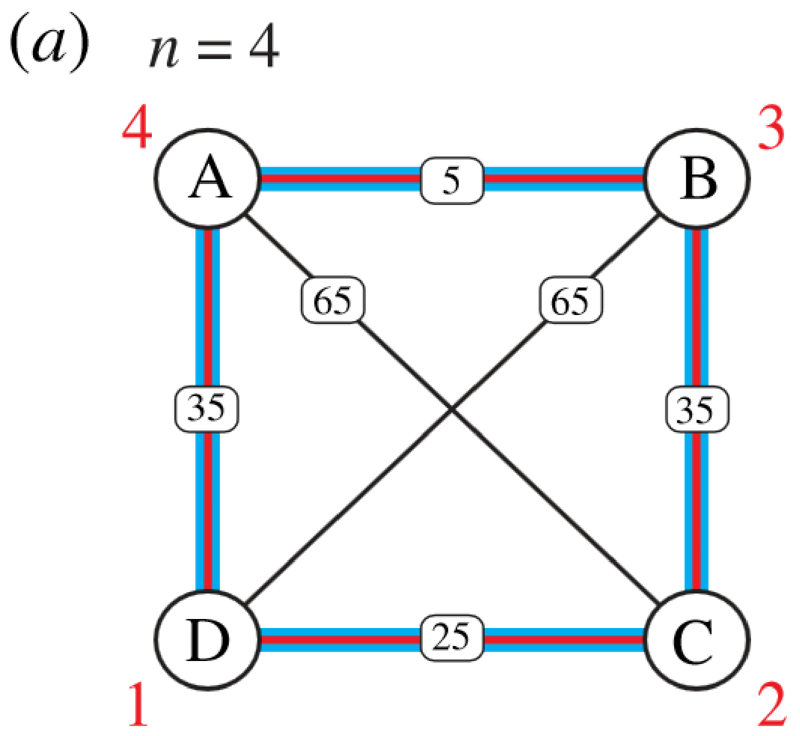
$$L_{Vk}(t+\Delta t) = 1 - \sigma_{1000,-0.5}\left(\sum_{Ul} W_{Vk,Ul} * \sigma_{35,0.6}\left(X_{Ul}(t)\right)\right)$$

(a) $n = 4$



$$L_{Vk}(t+\Delta t) = 1 - \sigma_{1000,-0.5}\left(\sum_{Ul} W_{Vk,Ul} * \sigma_{35,0.6}\left(X_{Ul}(t)\right)\right)$$





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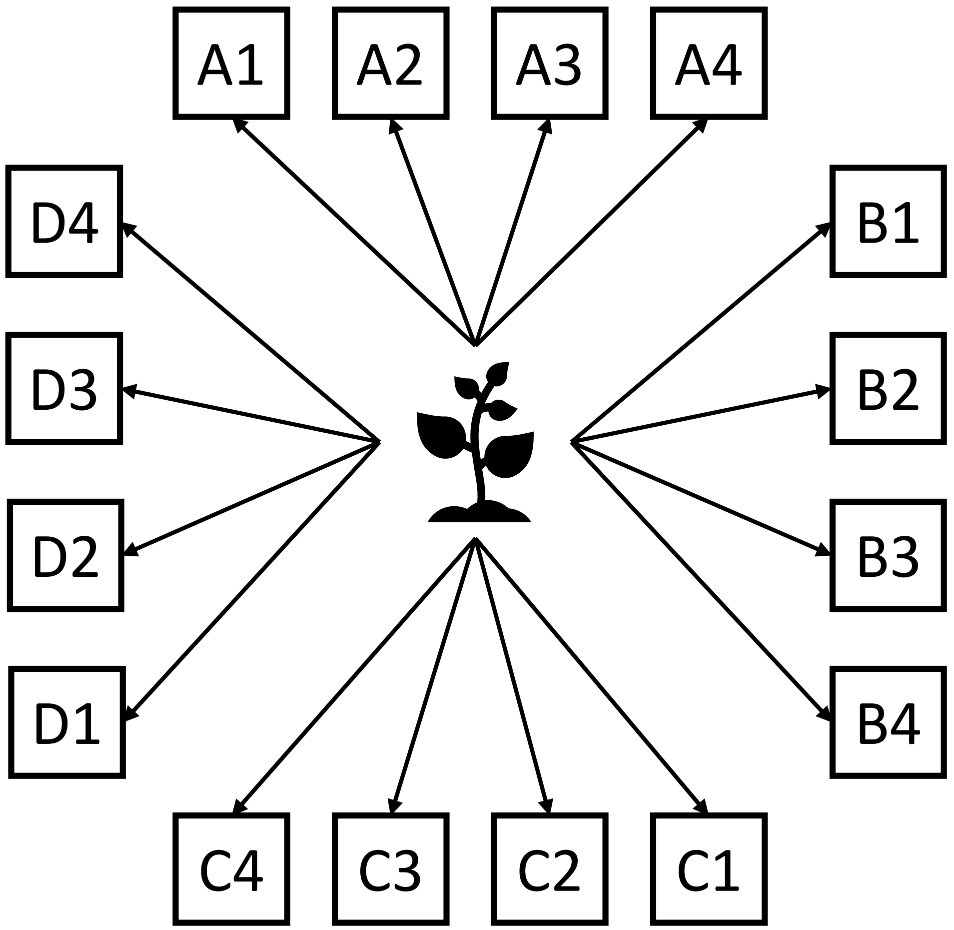

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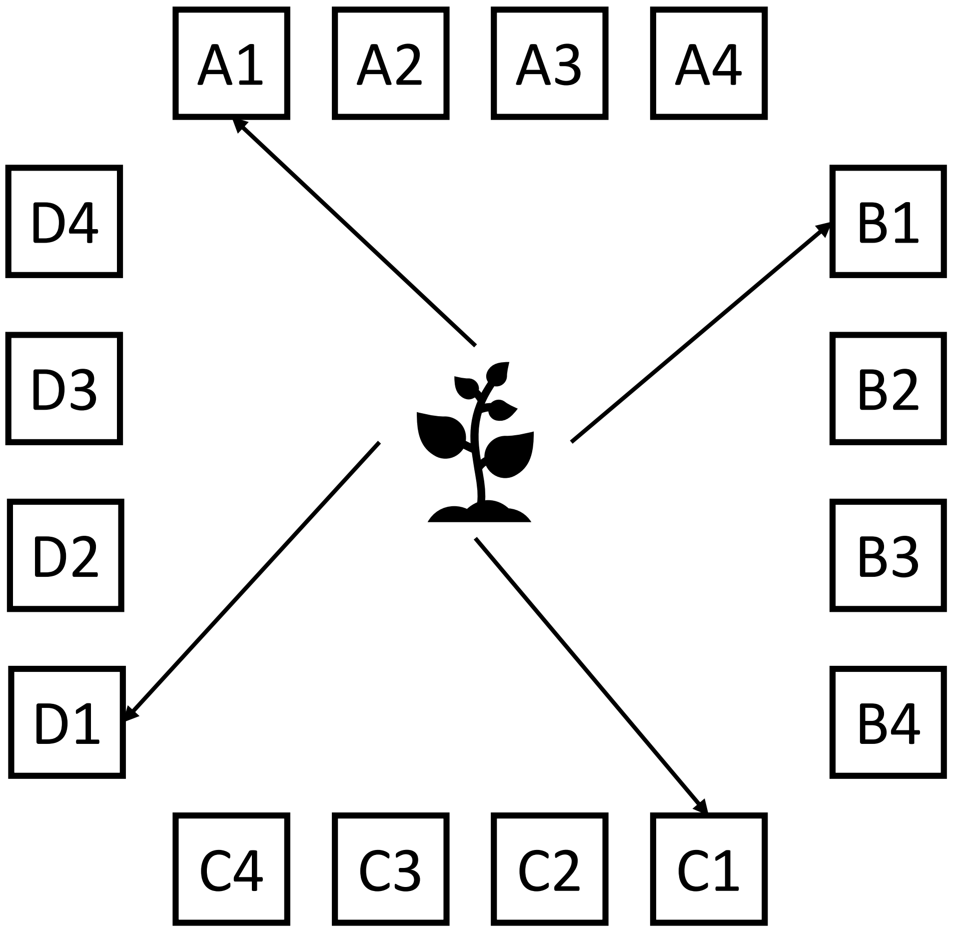

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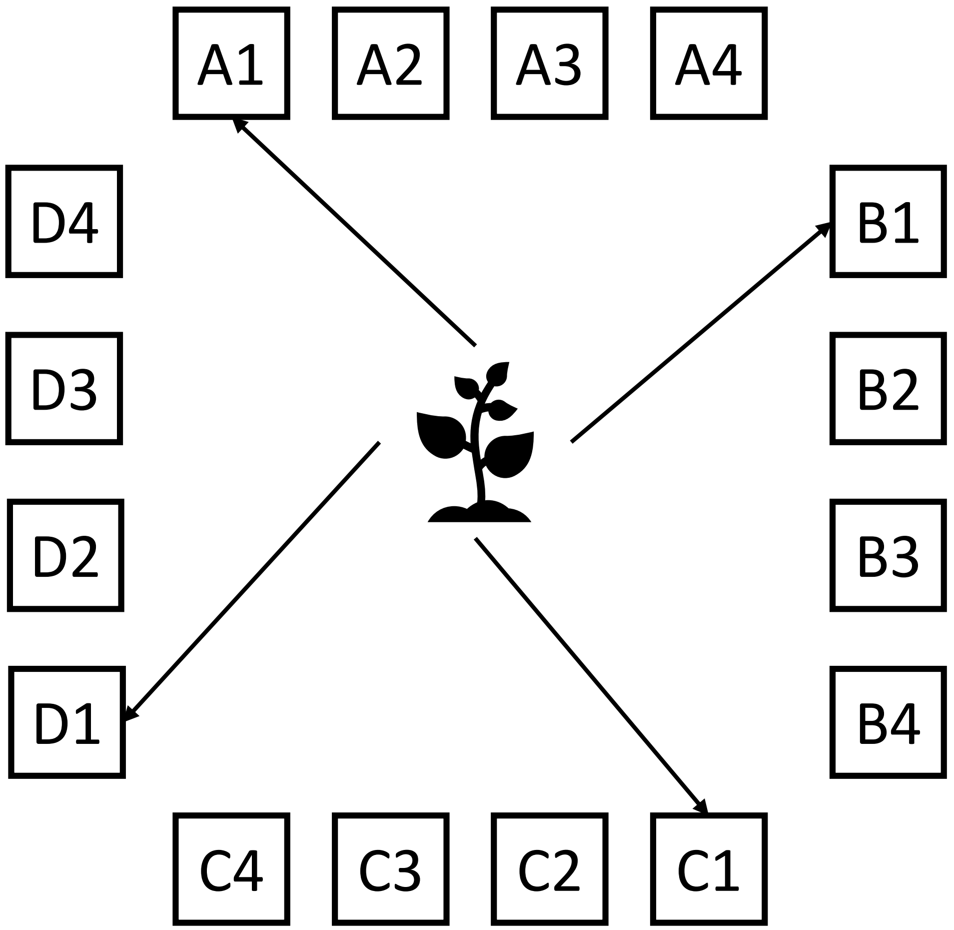
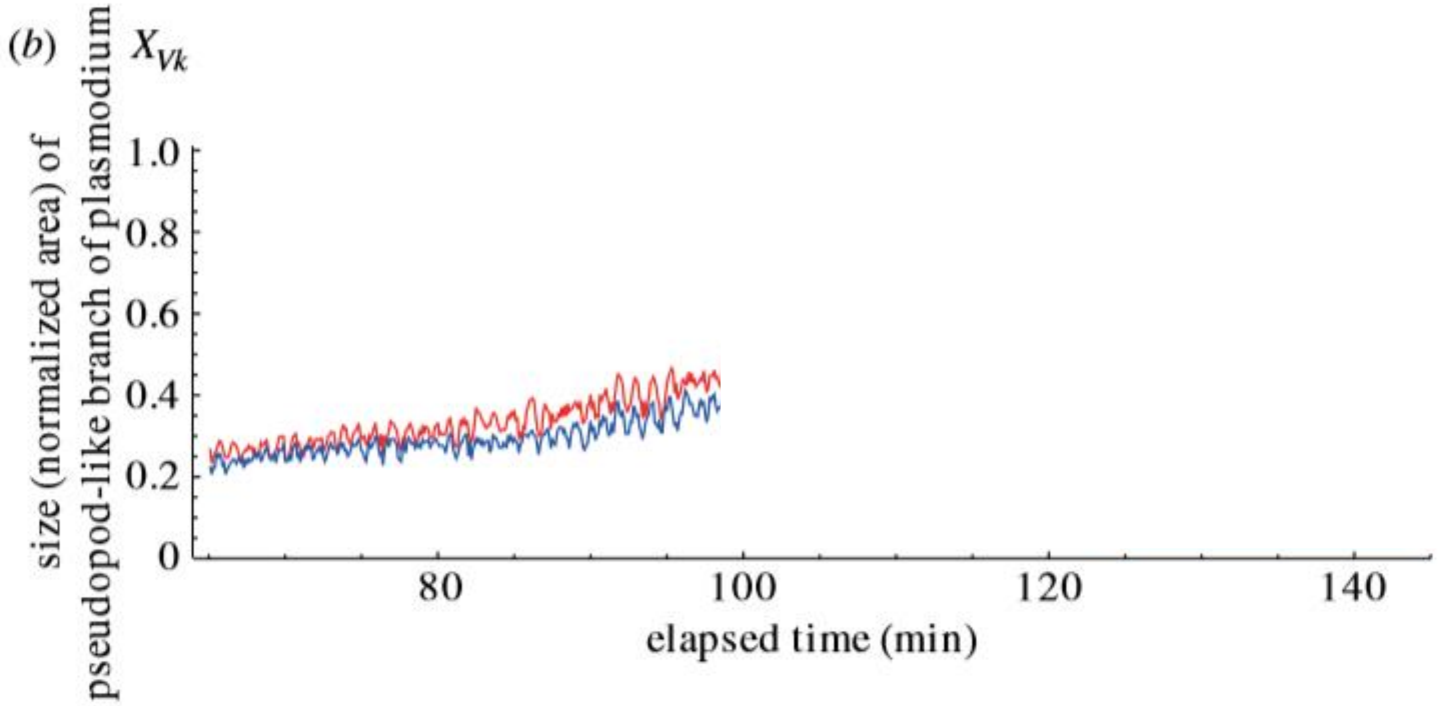
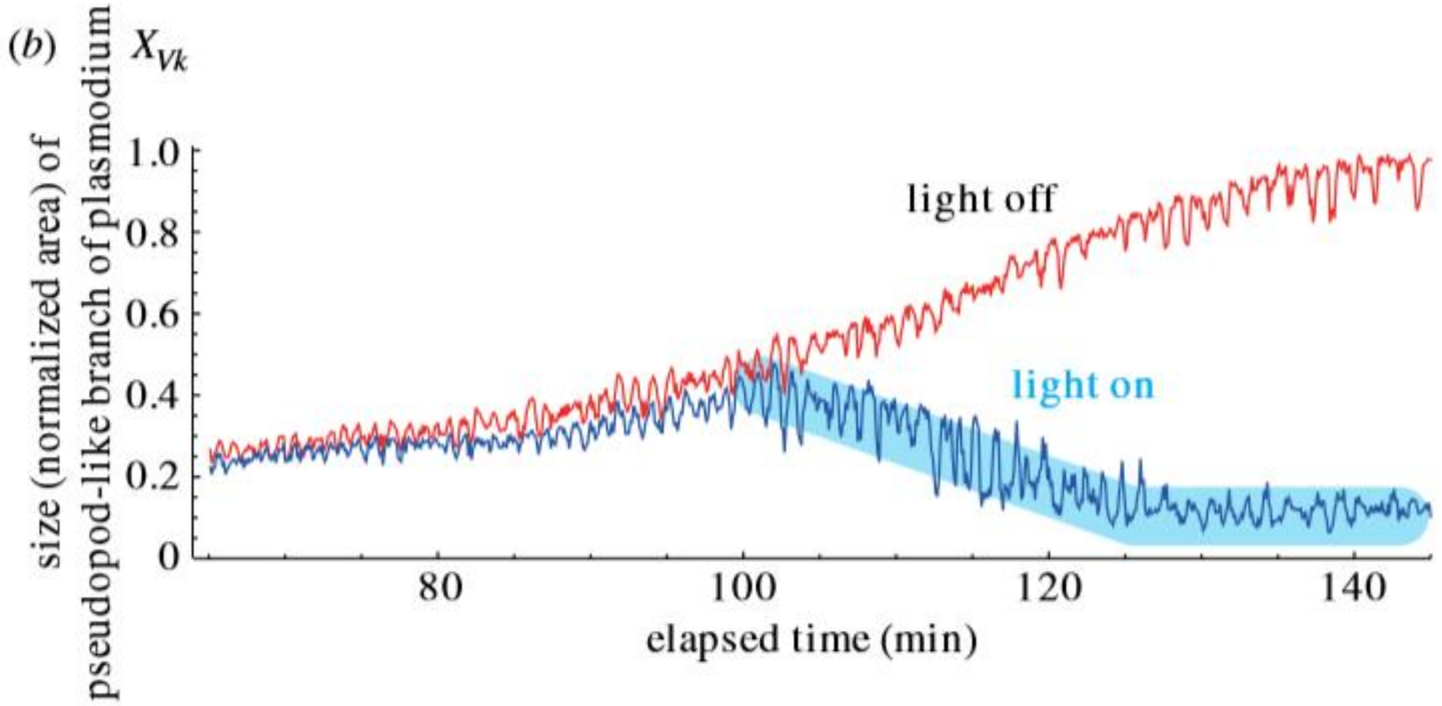


Wofür entscheidet sich die Amöbe?

$$L_{Vk}(t+\Delta t) = 1 - \sigma_{1000,-0.5}\left(\sum_{Ul} W_{Vk,Ul} * \sigma_{35,0.6}\big(X_{Ul}(t)\big)\right)$$



$$L_{Vk}(t + \Delta t) = 1 - \sigma_{1000,-0.5}\left(\sum_{Ul} W_{Vk,Ul} * \sigma_{35,0.6}\left(X_{Ul}(t)\right)\right)$$



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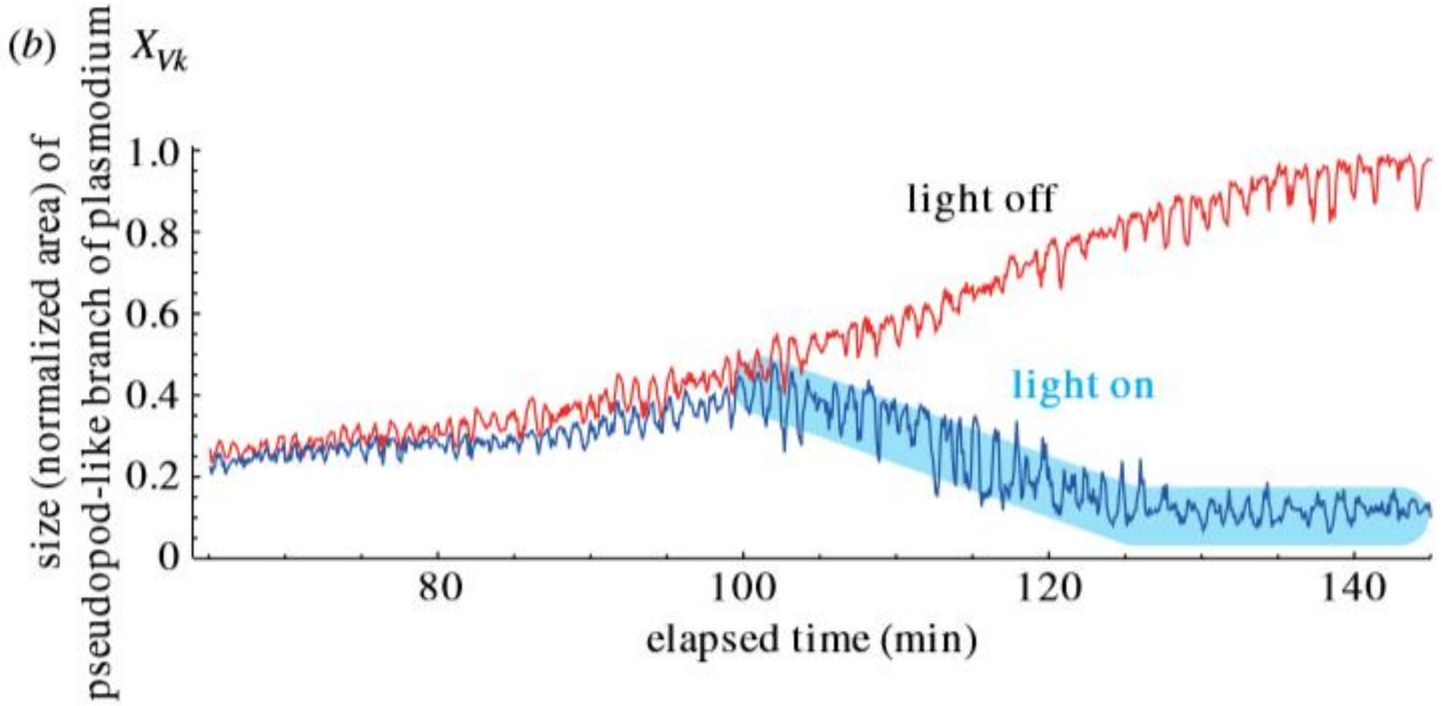
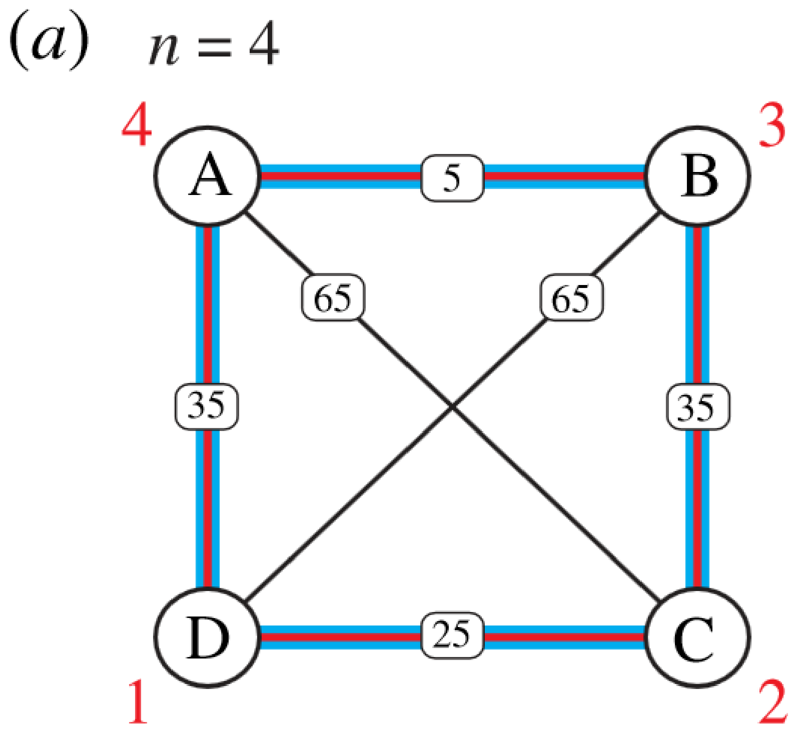


Wofür entscheidet sich die Amöbe?

→ Zufall!

$$L_{Vk}(t+\Delta t) = 1 - \sigma_{1000,-0.5}\left(\sum_{Ul} W_{Vk,Ul} * \sigma_{35,0.6}\left(X_{Ul}(t)\right)\right)$$

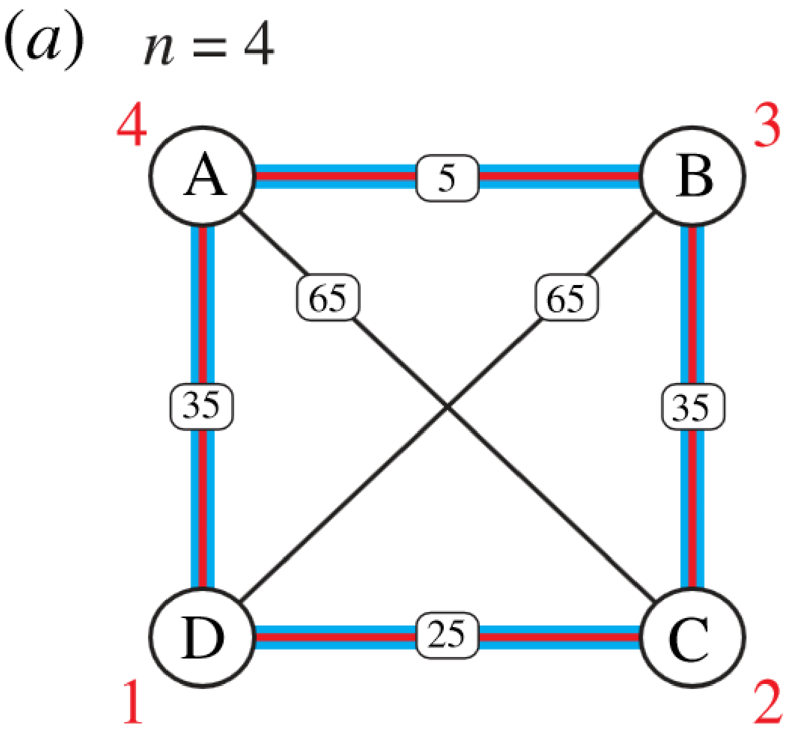


Wofür entscheidet sich der Pilz?

→ Zufall!

Ist das relevant?

$$L_{Vk}(t+\Delta t) = 1 - \sigma_{1000,-0.5}\left(\sum\nolimits_{Ul} W_{Vk,Ul} * \sigma_{35,0.6}\big(X_{Ul}(t)\big)\right)$$



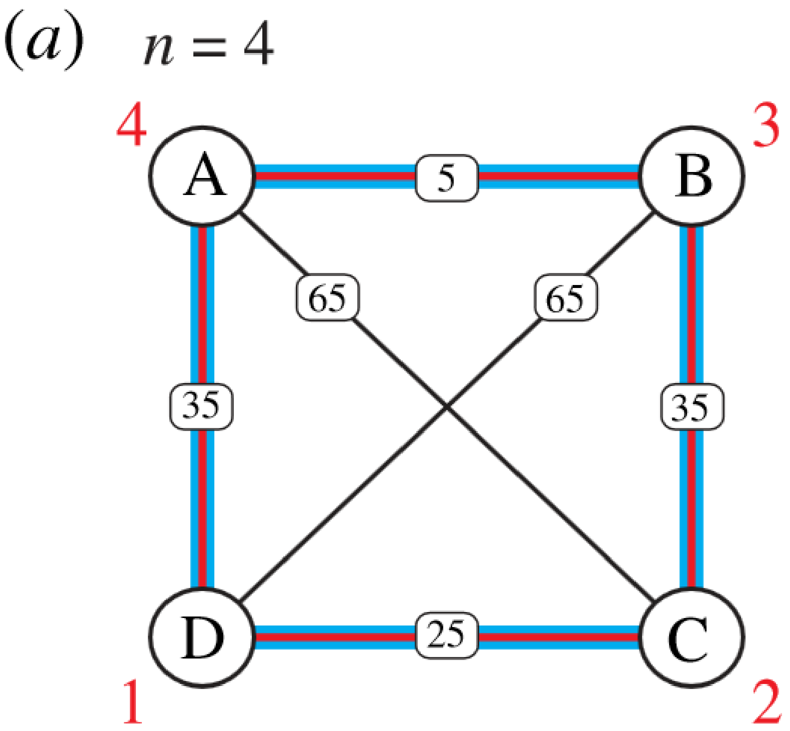
$\boldsymbol{D \rightarrow C \rightarrow B \rightarrow A \rightarrow D}$

Wofür entscheidet sich der Pilz?

→ Zufall!

Ist das relevant?

$$L_{Vk}(t+\Delta t) = 1 - \sigma_{1000,-0.5}\left(\sum\nolimits_{Ul} W_{Vk,Ul} * \sigma_{35,0.6}\big(X_{Ul}(t)\big)\right)$$



$D \rightarrow C \rightarrow B \rightarrow A \rightarrow D$

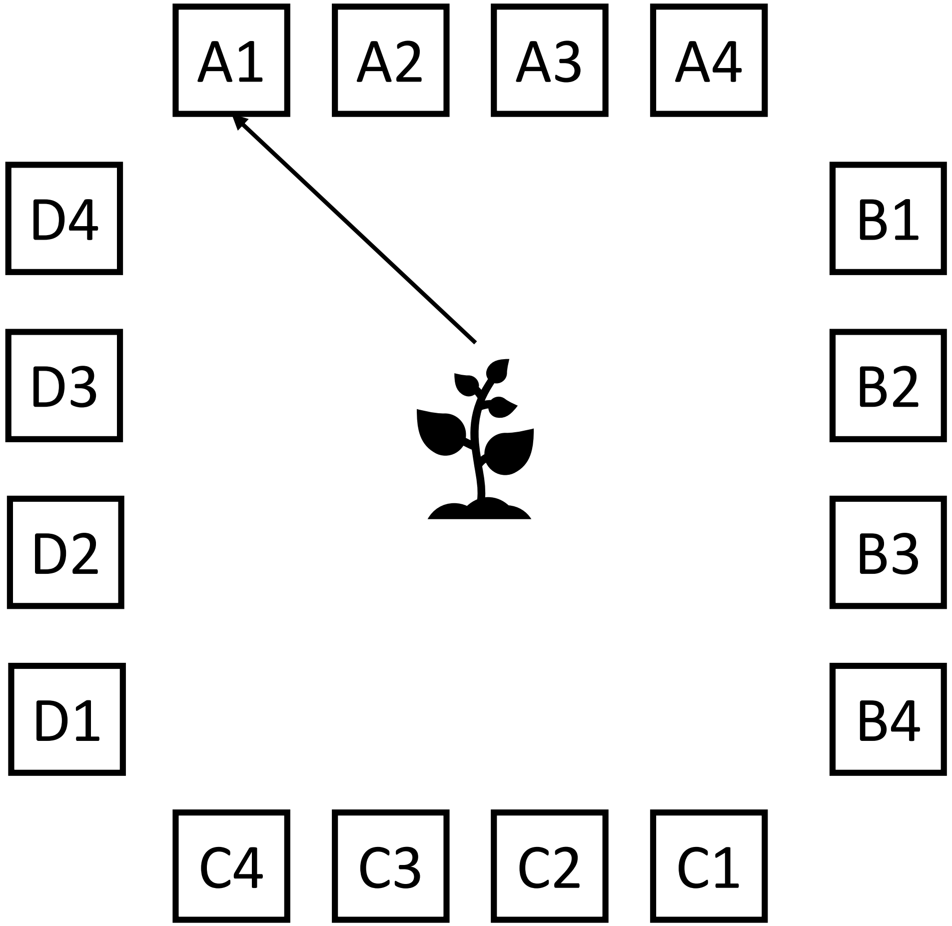
Wofür entscheidet sich der Pilz?

→ Zufall!

Ist das relevant?

→ Nein, da Rundkurs!

$$L_{Vk}(t+\Delta t) = 1 - \sigma_{1000,-0.5}\left(\sum\nolimits_{Ul} W_{Vk,Ul} * \sigma_{35,0.6}\big(X_{Ul}(t)\big)\right)$$



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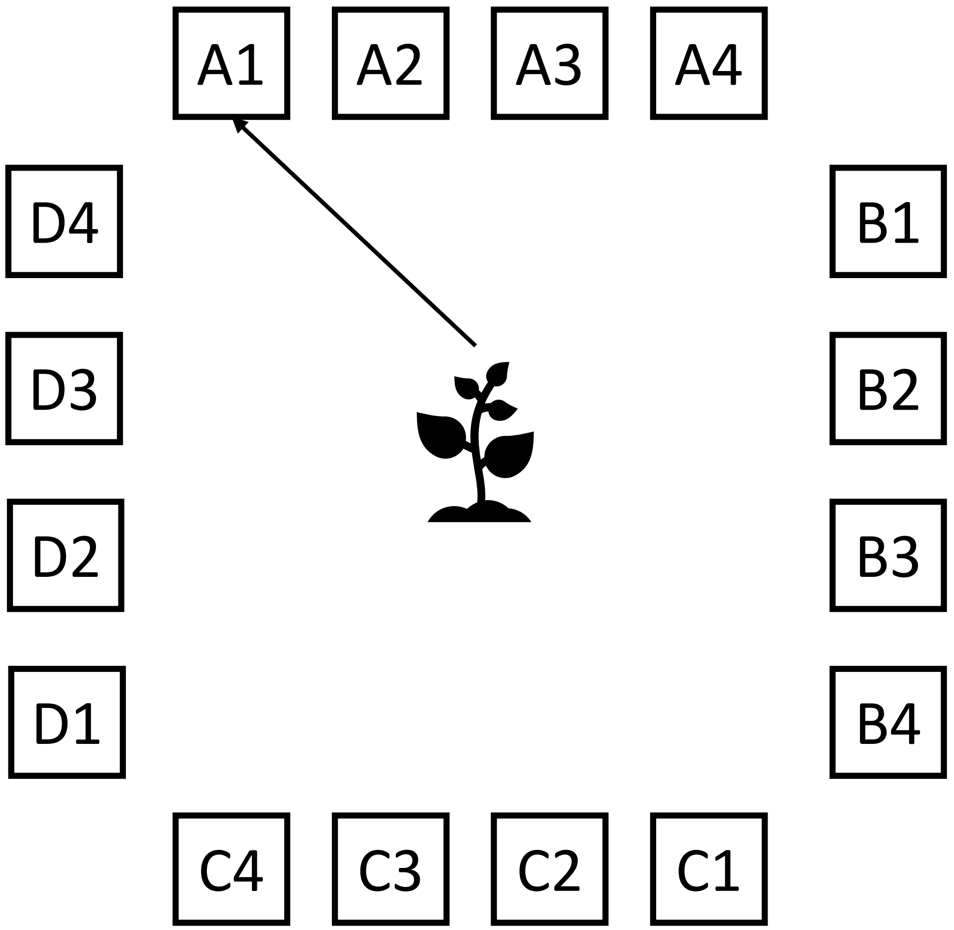

Leuchten A2, A3 & A4?

$$L_{Vk}(t+\Delta t) = 1 - \sigma_{1000,-0.5}\left(\sum_{Ul} W_{Vk,Ul} * \sigma_{35,0.6}\left(X_{Ul}(t)\right)\right)$$

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$$L_{Vk}(t+\Delta t) = 1 - \sigma_{1000,-0.5}\left(\sum\nolimits_{Ul} W_{Vk,Ul} * \sigma_{35,0.6}\left(X_{Ul}(t)\right)\right)$$

Für A2, A3 & A4 bei $\boldsymbol{Ul = A1}$

$$W_{Vk,Ul} \begin{cases} \boxed{-0.5 \quad \text{Wenn } V = U \text{ und } k \neq l} \\ -0.5 & \text{Wenn } V \neq U \text{ und } k = l \\ -v * dist(V,U) & \text{Wenn } V \neq U \text{ und } |k-l| = 1 \\ 0 & \text{Ansonsten} \end{cases}$$

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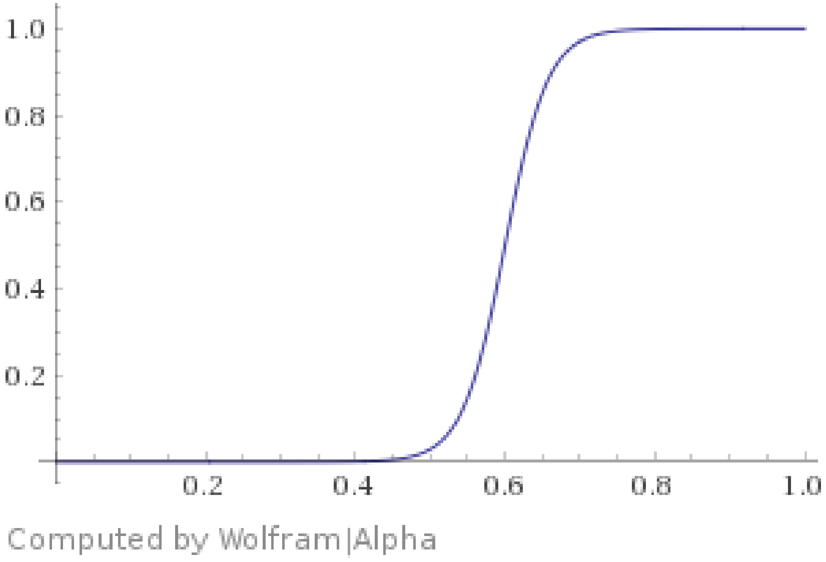
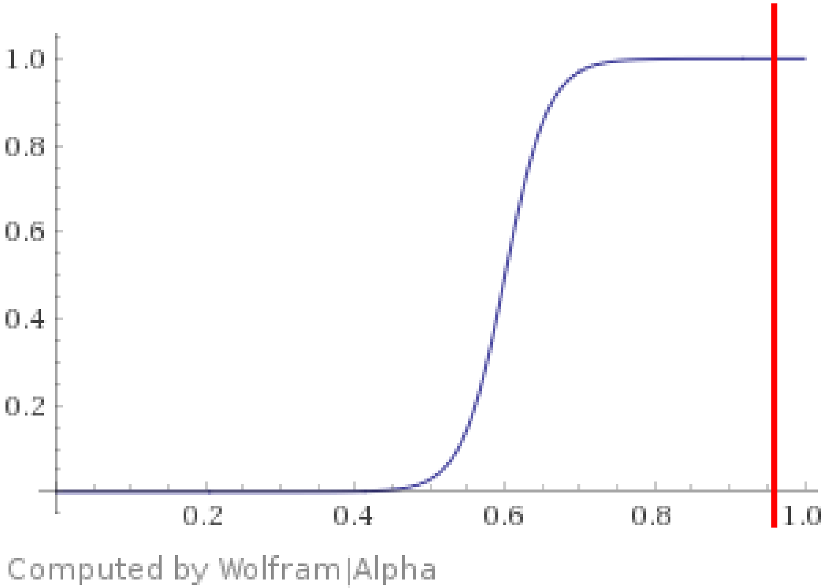


$$\sigma_{\gamma,\theta} = 1/(1 + \exp(-\underset{35}{\gamma} * (x - \underset{0.6}{\theta})))$$

- ➢ Sobald die Hälfte der Linie belegt ist steigt der Wert gegen 1

$$L_{Vk}(t+\Delta t) = 1 - \sigma_{1000,-0.5}\left(\sum_{Ul} W_{Vk,Ul} * \sigma_{35,0.6}\big(X_{Ul}(t)\big)\right)$$



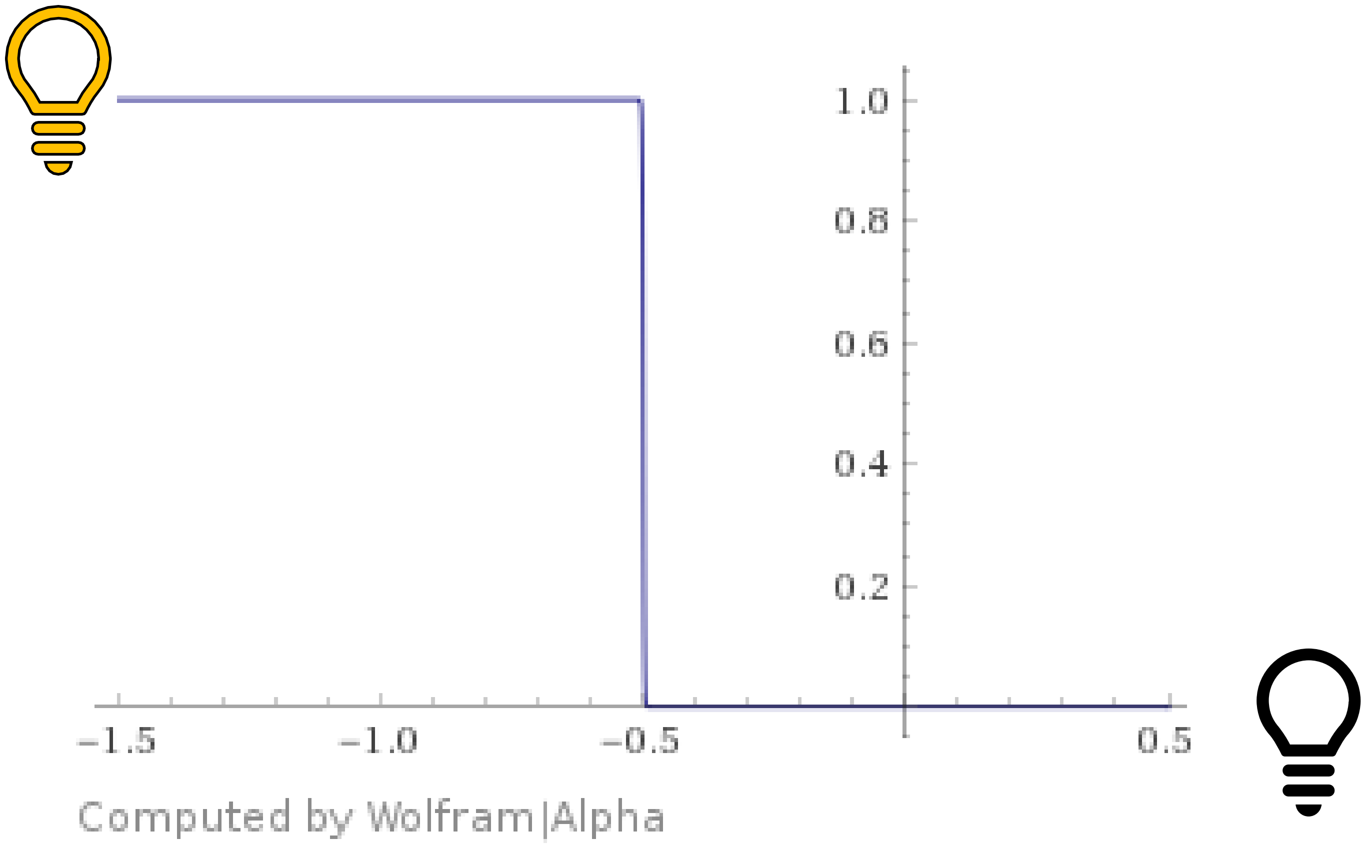
$$\sigma_{\gamma,\theta} = 1/(1+\exp(-\overset{35}{\gamma} * (x-\overset{0.6}{\theta})))$$

- Sobald die Hälfte der Linie belegt ist steigt der Wert gegen 1

$$X_{A1} \approx 1$$

$$X_{[A-D][1-4]/(A1)} \approx 0$$

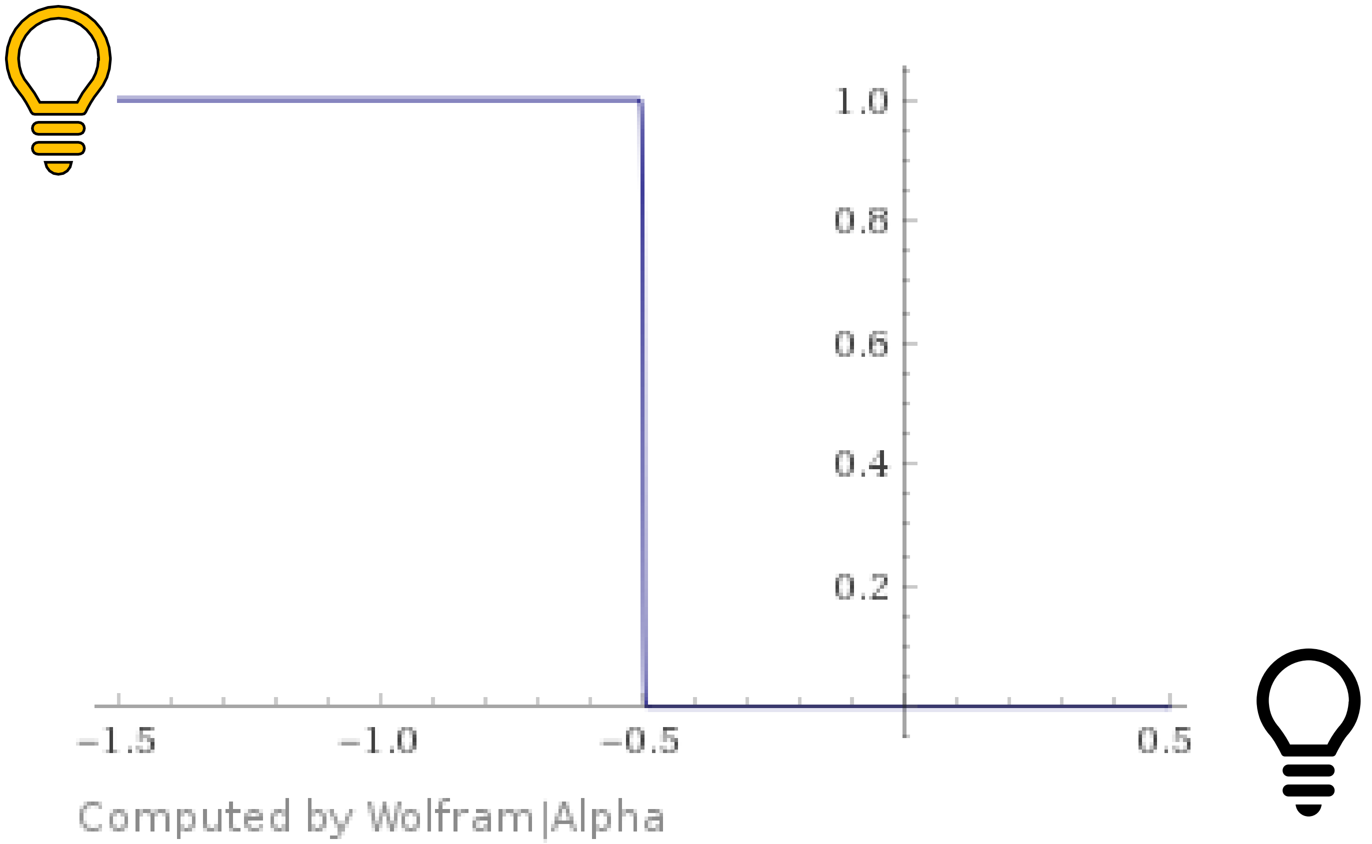
$$L_{Vk}(t+\Delta t) = 1 - \sigma_{1000,-0.5}\underbrace{\left(\sum_{Ul} W_{Vk,Ul} * \sigma_{35,0.6}\big(X_{Ul}(t)\big)\right)}_{x}$$



Nachbar oder
Gegenüber belegt

Nachbar und
Gegenüber frei

$$L_{Vk}(t + \Delta t) = 1 - \sigma_{1000,-0.5}\left(\sum_{Ul} \underbrace{W_{Vk,Ul}}_{-0.5} * \underbrace{\sigma_{35,0.6}\big(X_{Ul}(t)\big)}_{1}\right)$$



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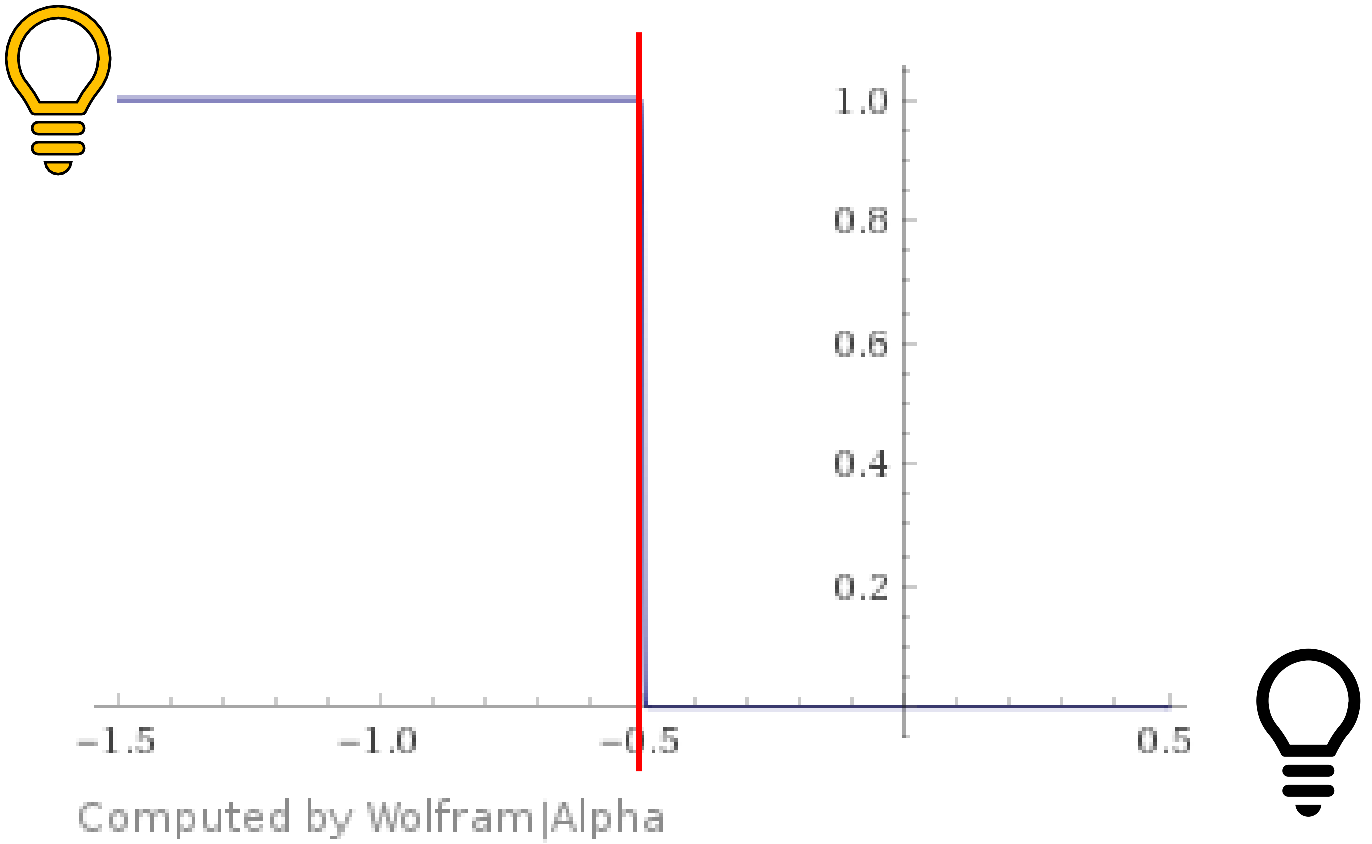
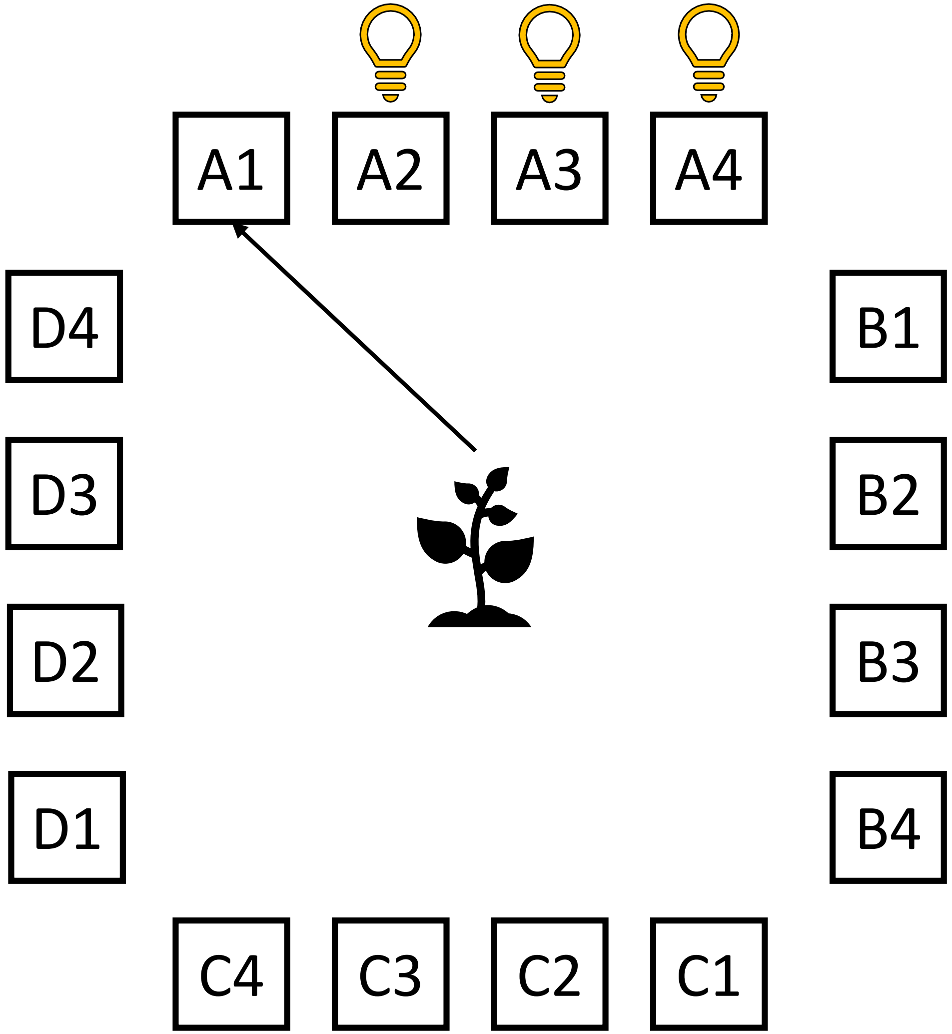


$$\boxed{L_{A2,A3,A4} = 0.5}$$

$$L_{Vk}(t+\Delta t) = 1 - \sigma_{1000,-0.5}\left(\sum_{Ul} W_{Vk,Ul} * \sigma_{35,0.6}\left(X_{Ul}(t)\right)\right)$$



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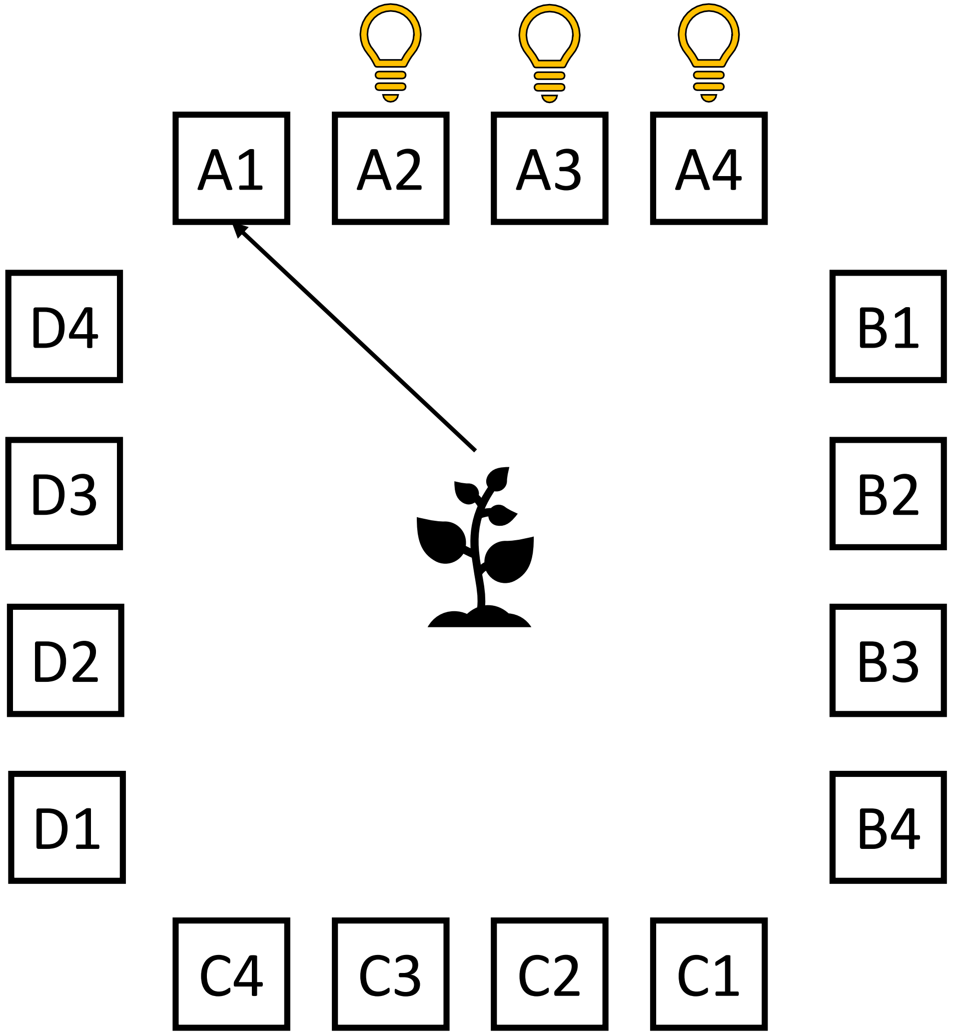

Leuchten B1, C1 & D1?

$$L_{Vk}(t+\Delta t) = 1 - \sigma_{1000,-0.5}\left(\sum_{Ul} W_{Vk,Ul} * \sigma_{35,0.6}\big(X_{Ul}(t)\big)\right)$$

Für B1, C1 & D1 bei $\boldsymbol{Ul = A1}$

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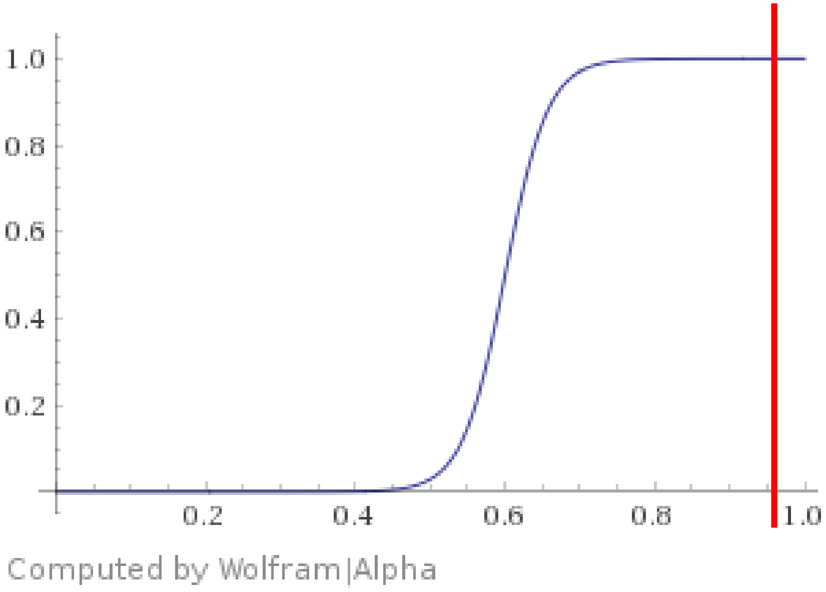
$$L_{Vk}(t+\Delta t) = 1 - \sigma_{1000,-0.5}\left(\sum_{Ul} W_{Vk,Ul} * \sigma_{35,0.6}\big(X_{Ul}(t)\big)\right)$$



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- Sobald die Hälfte der Linie belegt ist steigt der Wert gegen 1

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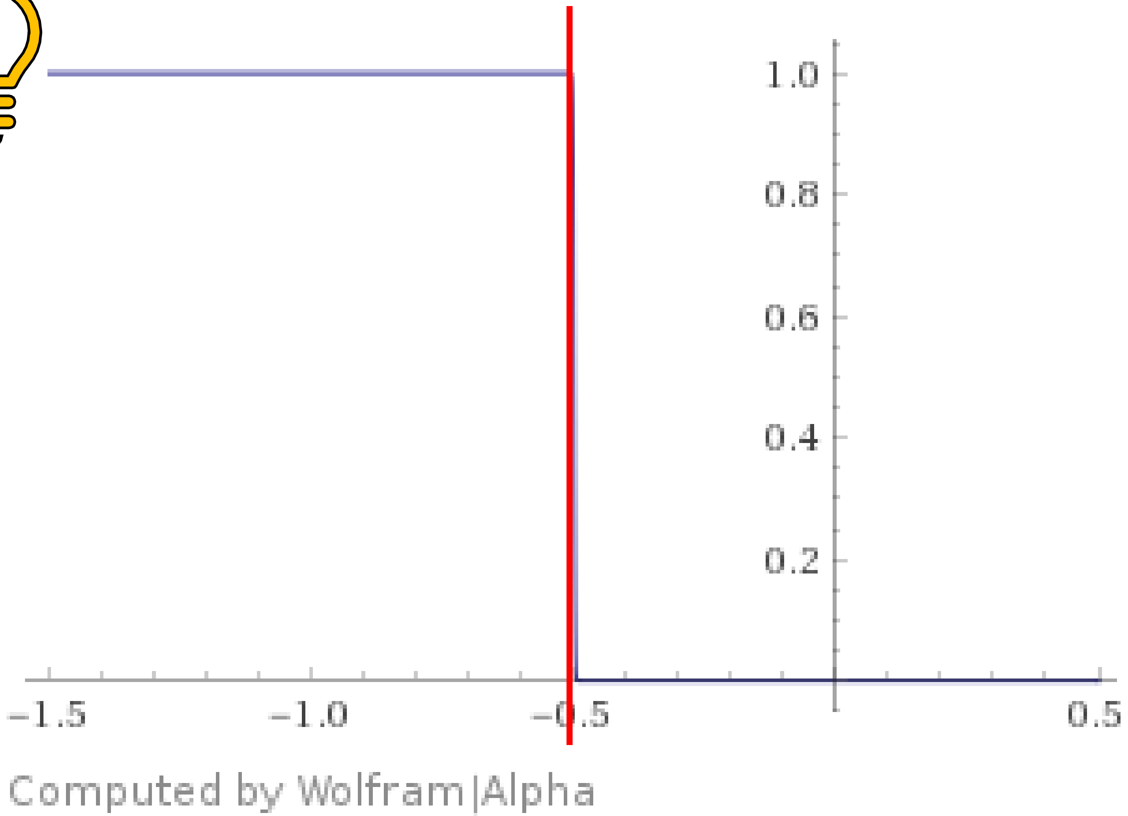
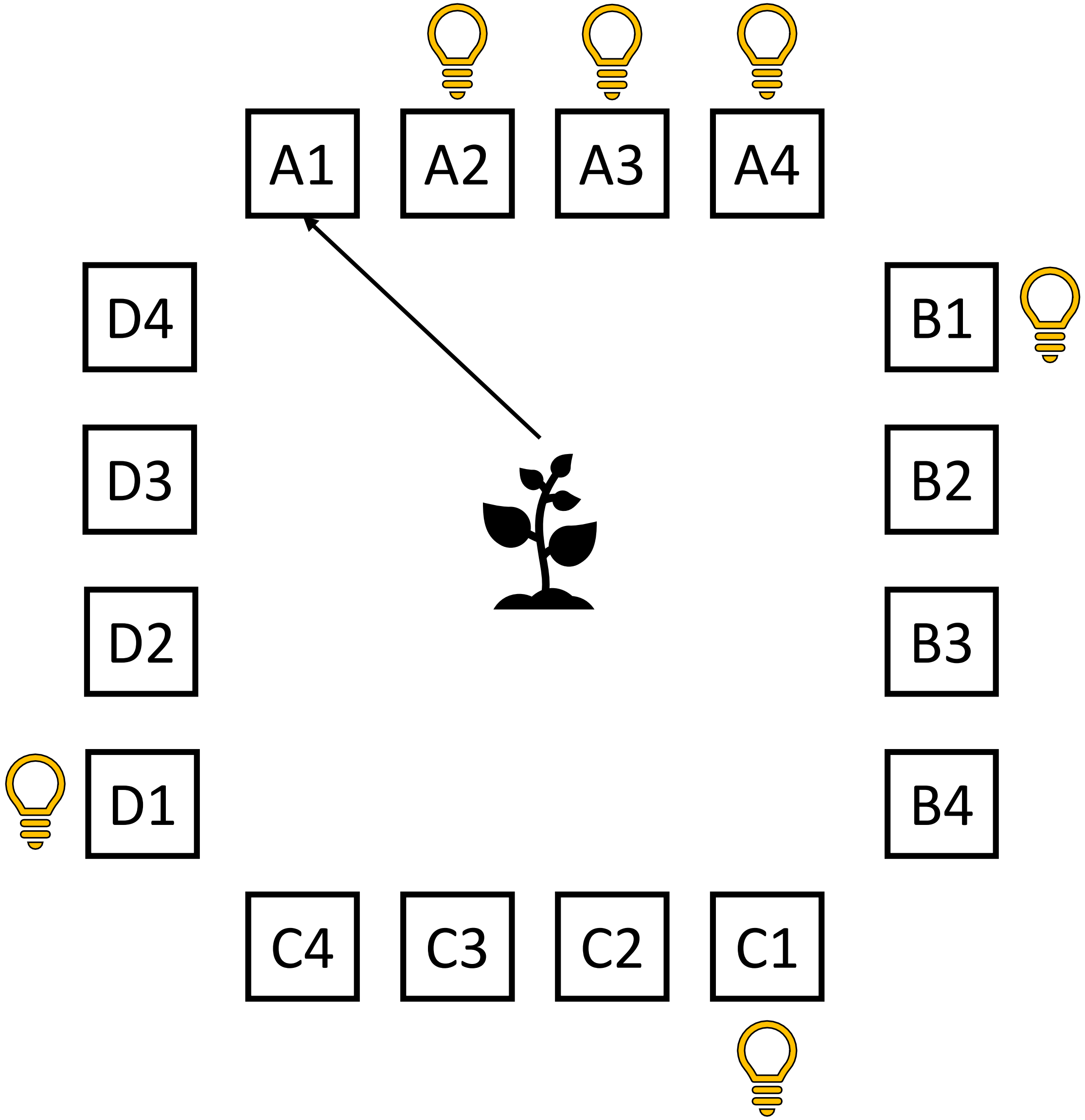
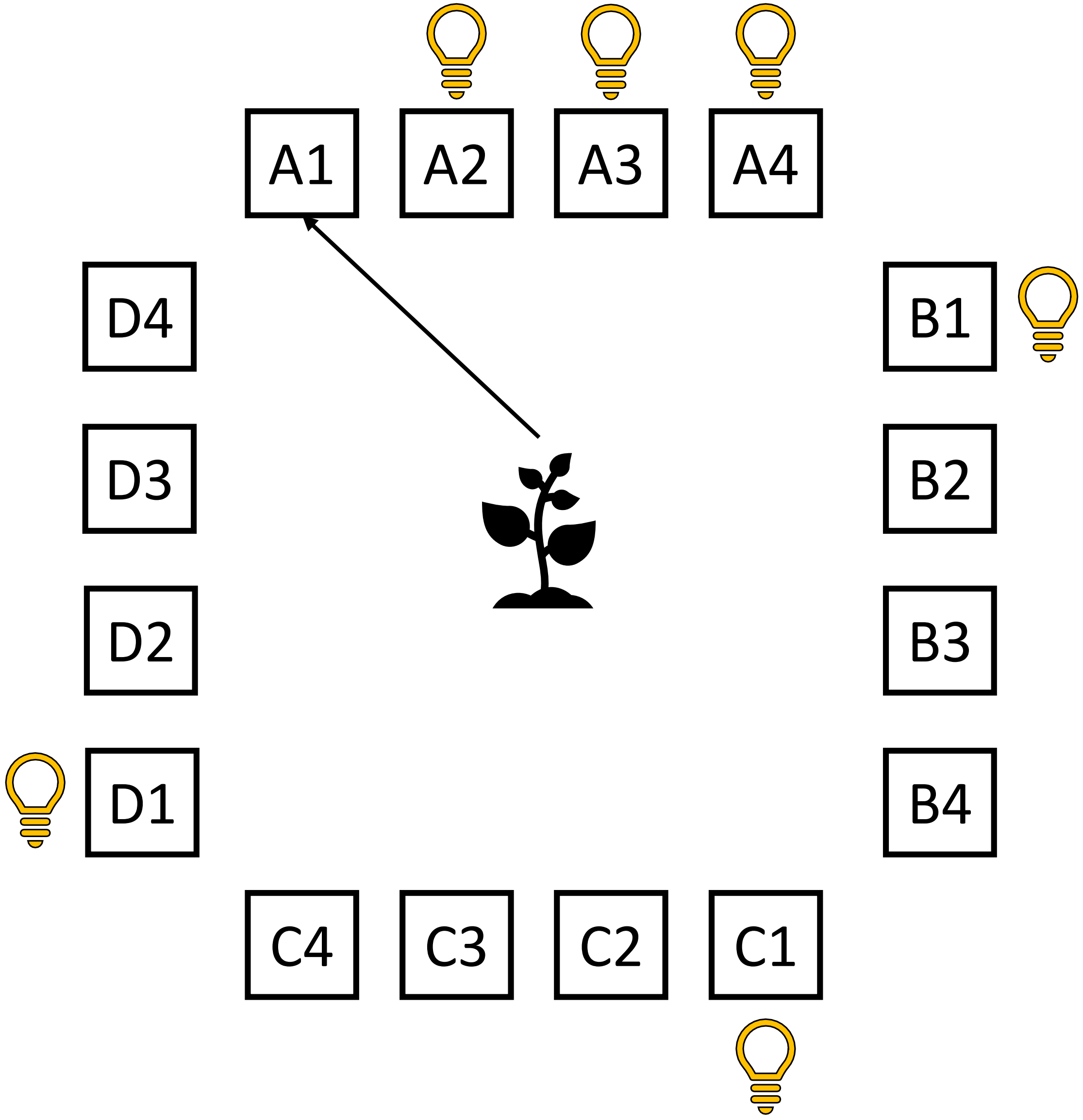


$$\boxed{L_{B1,C1,D1} = 0.5}$$

$$L_{Vk}(t + \Delta t) = 1 - \sigma_{1000,-0.5}\left(\sum_{Ul} W_{Vk,Ul} * \sigma_{35,0.6}\left(X_{Ul}(t)\right)\right)$$



$$L_{Vk}(t+\Delta t) = 1 - \sigma_{1000,-0.5}\left(\sum_{Ul} W_{Vk,Ul} * \sigma_{35,0.6}\left(X_{Ul}(t)\right)\right)$$



Leuchten B2, C2 & D2?

$$L_{Vk}(t+\Delta t) = 1 - \sigma_{1000,-0.5}\left(\sum_{Ul} W_{Vk,Ul} * \sigma_{35,0.6}\left(X_{Ul}(t)\right)\right)$$

Für B2, C2 & D2 bei $\boldsymbol{Ul = A1}$

$$W_{Vk,Ul} \begin{cases} -0.5 & \text{Wenn } V = U \text{ und } k \neq l \\ -0.5 & \text{Wenn } V \neq U \text{ und } k = l \\ \boxed{-v * dist(V,U) \quad \text{Wenn } V \neq U \text{ und } |k-l| = 1} \\ 0 & \text{Ansonsten} \end{cases}$$

$$L_{Vk}(t + \Delta t) = 1 - \sigma_{1000,-0.5}\left(\sum\nolimits_{Ul} W_{Vk,Ul} * \sigma_{35,0.6}\left(X_{Ul}(t)\right)\right)$$

Für B2, C2 & D2 bei $\boldsymbol{Ul = A1}$

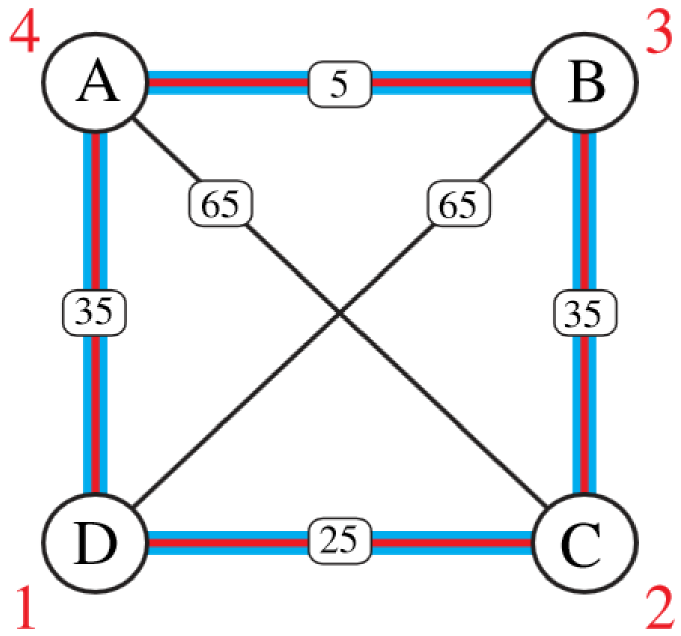
$$W_{Vk,Ul} \begin{cases} -0.5 & \text{Wenn } V = U \text{ und } k \neq l \\ -0.5 & \text{Wenn } V \neq U \text{ und } k = l \\ \boxed{-v * dist(V,U) \quad \text{Wenn } V \neq U \text{ und } |k - l| = 1} \\ 0 & \text{Ansonsten} \end{cases}$$

$$\boldsymbol{n = 4 \rightarrow v = 0.00495}$$

$$L_{Vk}(t+\Delta t) = 1 - \sigma_{1000,-0.5}\left(\sum_{Ul} W_{Vk,Ul} * \sigma_{35,0.6}\left(X_{Ul}(t)\right)\right)$$

$$-v * dist(V,U) \qquad n = 4 \rightarrow v = 0.00495$$

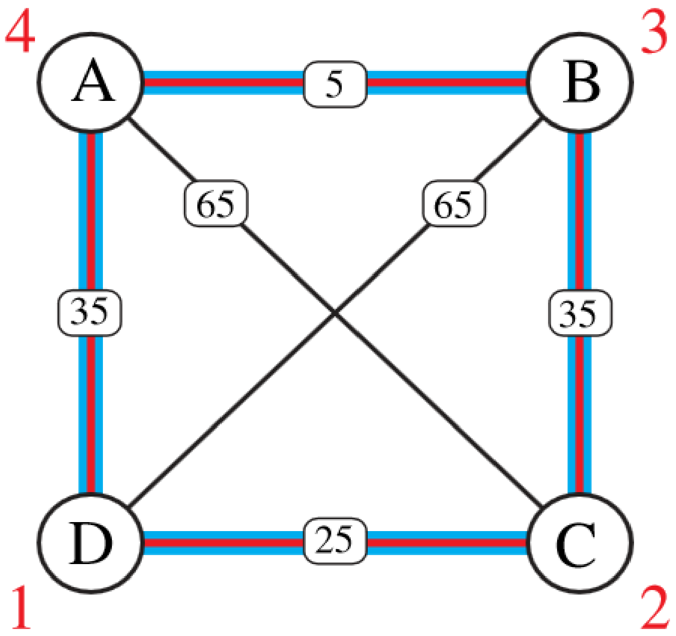
(a) $n = 4$



$$L_{Vk}(t+\Delta t) = 1 - \sigma_{1000,-0.5}\left(\sum_{Ul} W_{Vk,Ul} * \sigma_{35,0.6}\left(X_{Ul}(t)\right)\right)$$

$-v * dist(V,U)$ $\qquad$ $n = 4 \rightarrow v = 0.00495$

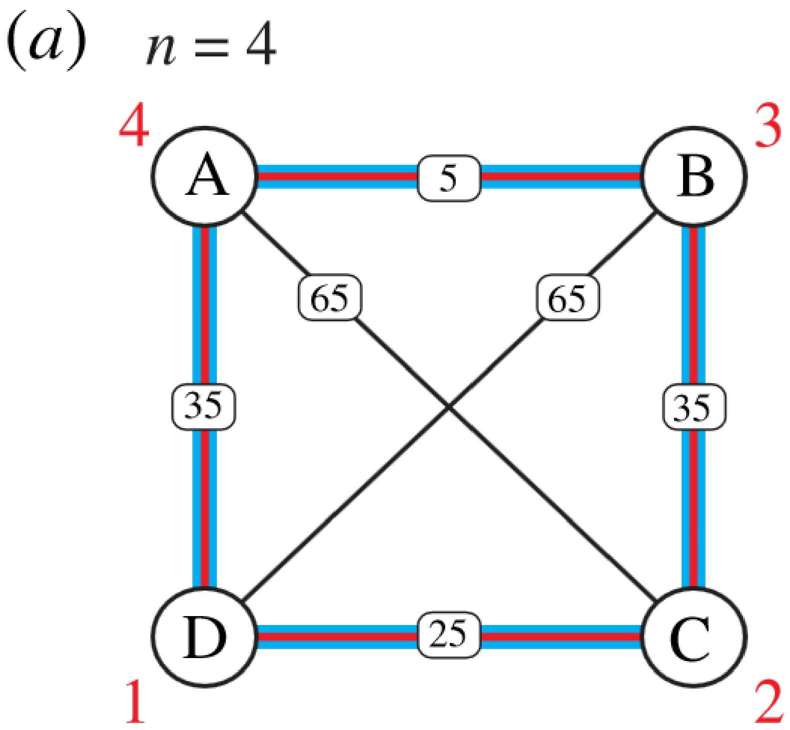
(a) $n = 4$



$$W_{A1,B2} = -0.00495 * 5 = -0.02475$$

$$L_{Vk}(t+\Delta t) = 1 - \sigma_{1000,-0.5}\left(\sum_{Ul} W_{Vk,Ul} * \sigma_{35,0.6}\left(X_{Ul}(t)\right)\right)$$

$-v * dist(V,U)$ $\qquad$ $n = 4 \rightarrow v = 0.00495$

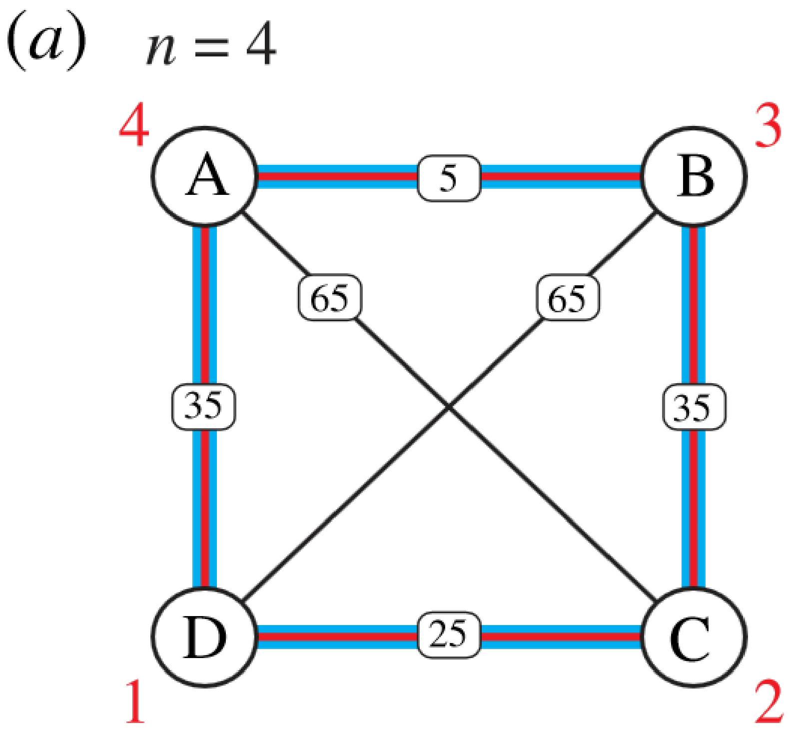


$$W_{A1,B2} = -0.00495 * 5 = -0.02475$$

$$W_{A1,C2} = -0.00495 * 65 = -0.32175$$

$$L_{Vk}(t+\Delta t) = 1 - \sigma_{1000,-0.5}\left(\sum_{Ul} W_{Vk,Ul} * \sigma_{35,0.6}\big(X_{Ul}(t)\big)\right)$$

$-v * dist(V,U)$ $\quad$ $n = 4 \rightarrow v = 0.00495$



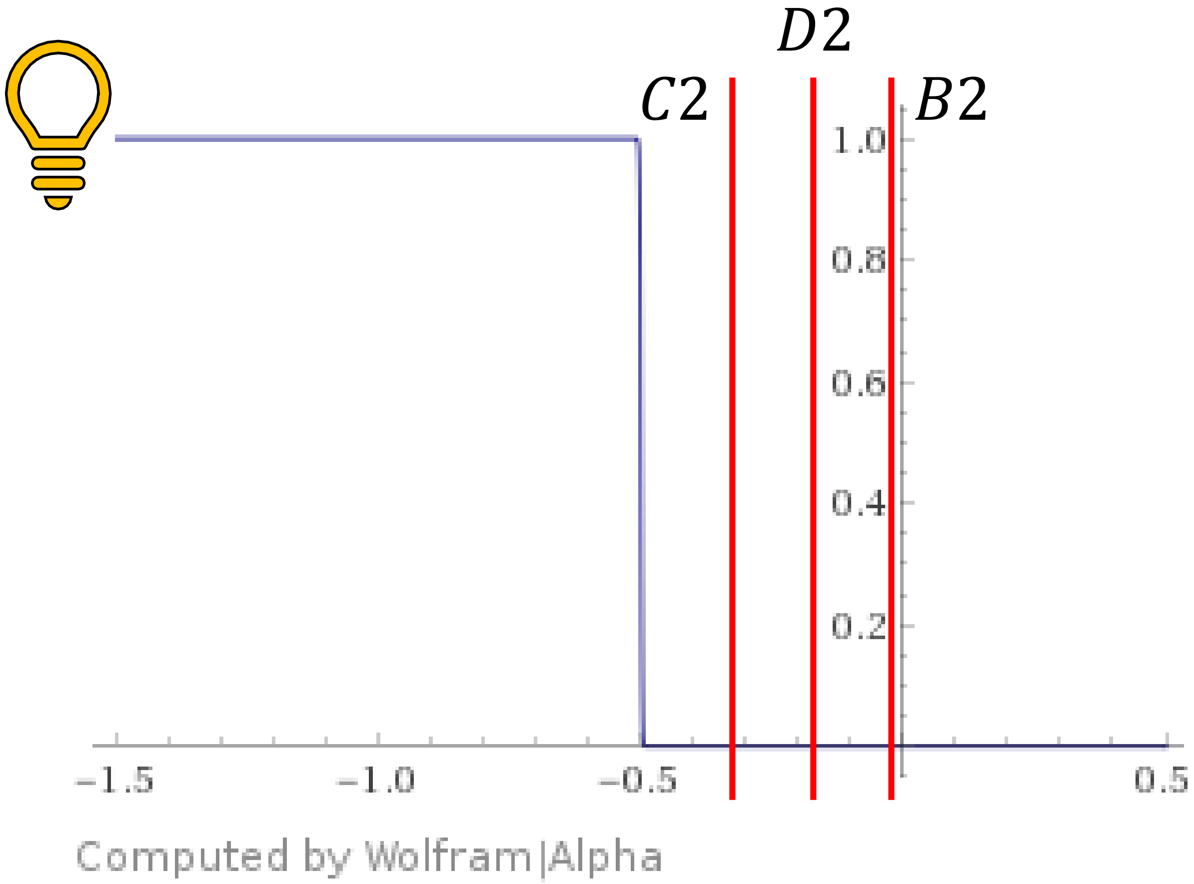
$$W_{B2,A1} = -0.00495 * 5 = -0.02475$$

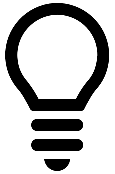
$$W_{C2,A1} = -0.00495 * 65 = -0.32175$$

$$W_{D2,A1} = -0.00495 * 35 = -0.17325$$

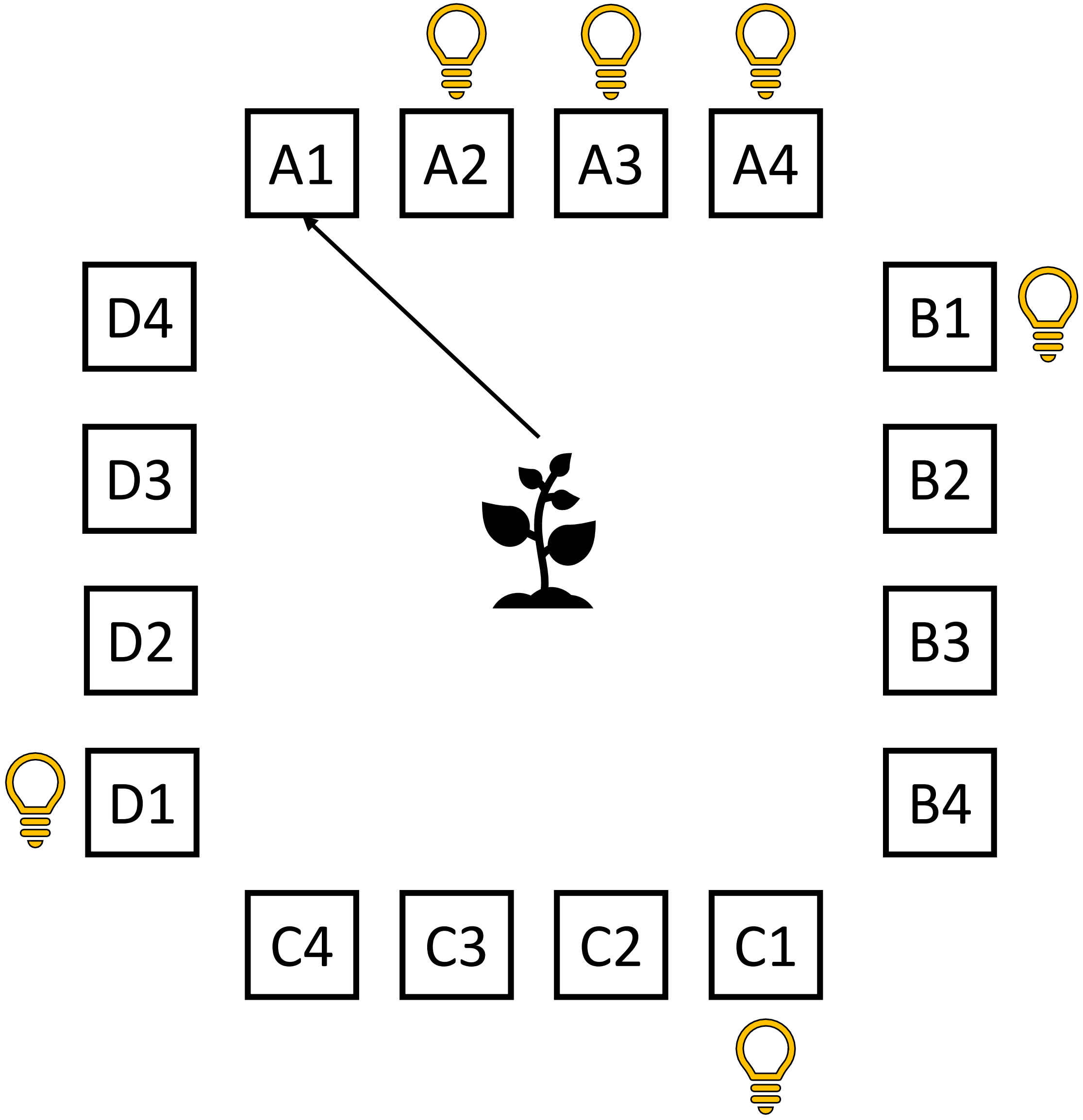
$$L_{Vk}(t+\Delta t) = 1 - \sigma_{1000,-0.5}\left(\sum_{Ul} \underbrace{W_{Vk,Ul}} * \underbrace{\sigma_{35,0.6}\left(X_{Ul}(t)\right)}_{1}\right)$$

$$W_{B2,A1} = -0.02475$$
$$W_{C2,A1} = -0.32175$$
$$W_{D2,A1} = -0.17325$$





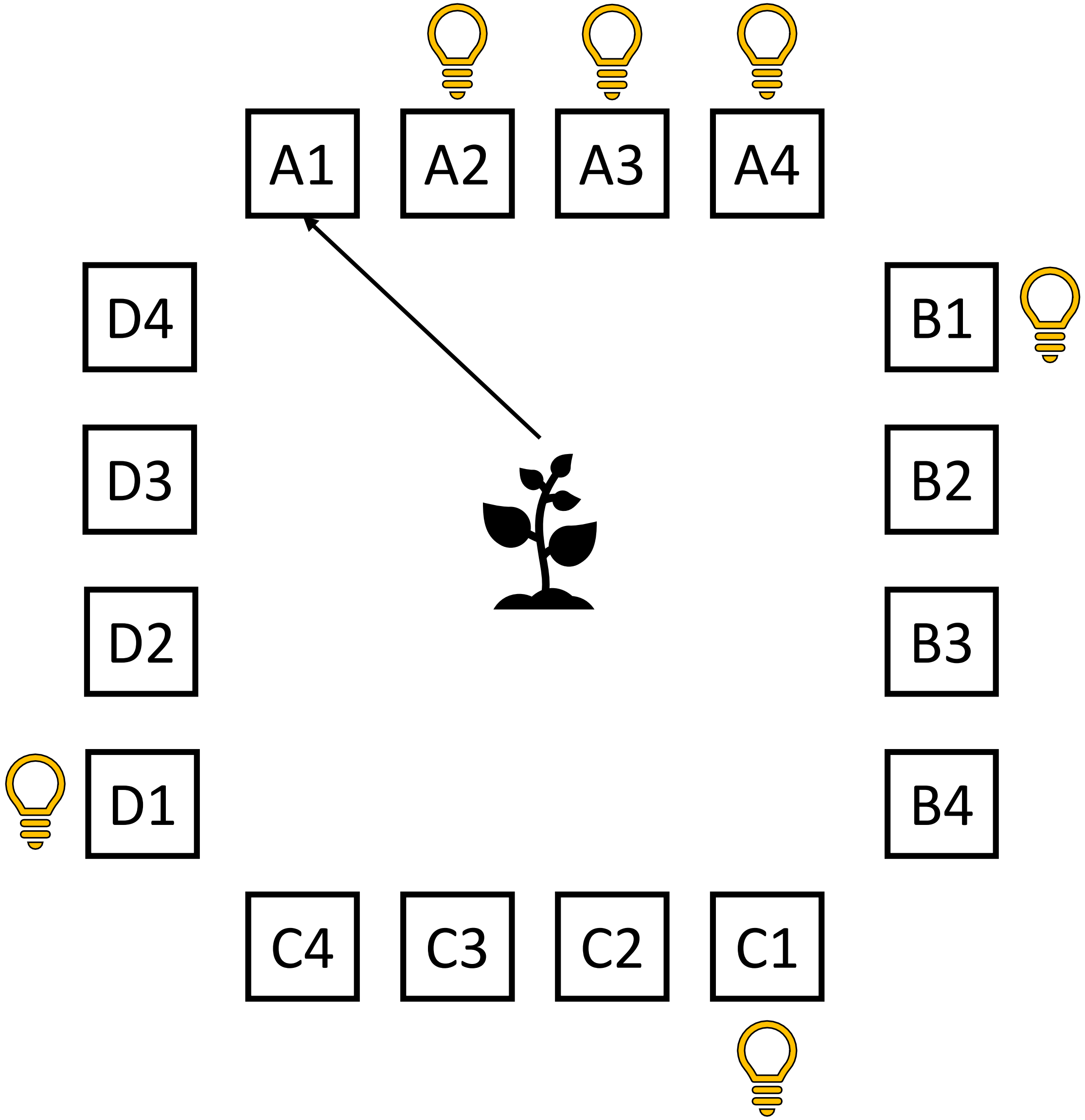
$$L_{Vk}(t+\Delta t) = 1 - \sigma_{1000,-0.5}\left(\sum_{Ul} W_{Vk,Ul} * \sigma_{35,0.6}\big(X_{Ul}(t)\big)\right)$$



Leuchten B2, C2 & D2?

→ Nein

$$L_{Vk}(t+\Delta t) = 1 - \sigma_{1000,-0.5}\left(\sum_{Ul} W_{Vk,Ul} * \sigma_{35,0.6}\left(X_{Ul}(t)\right)\right)$$



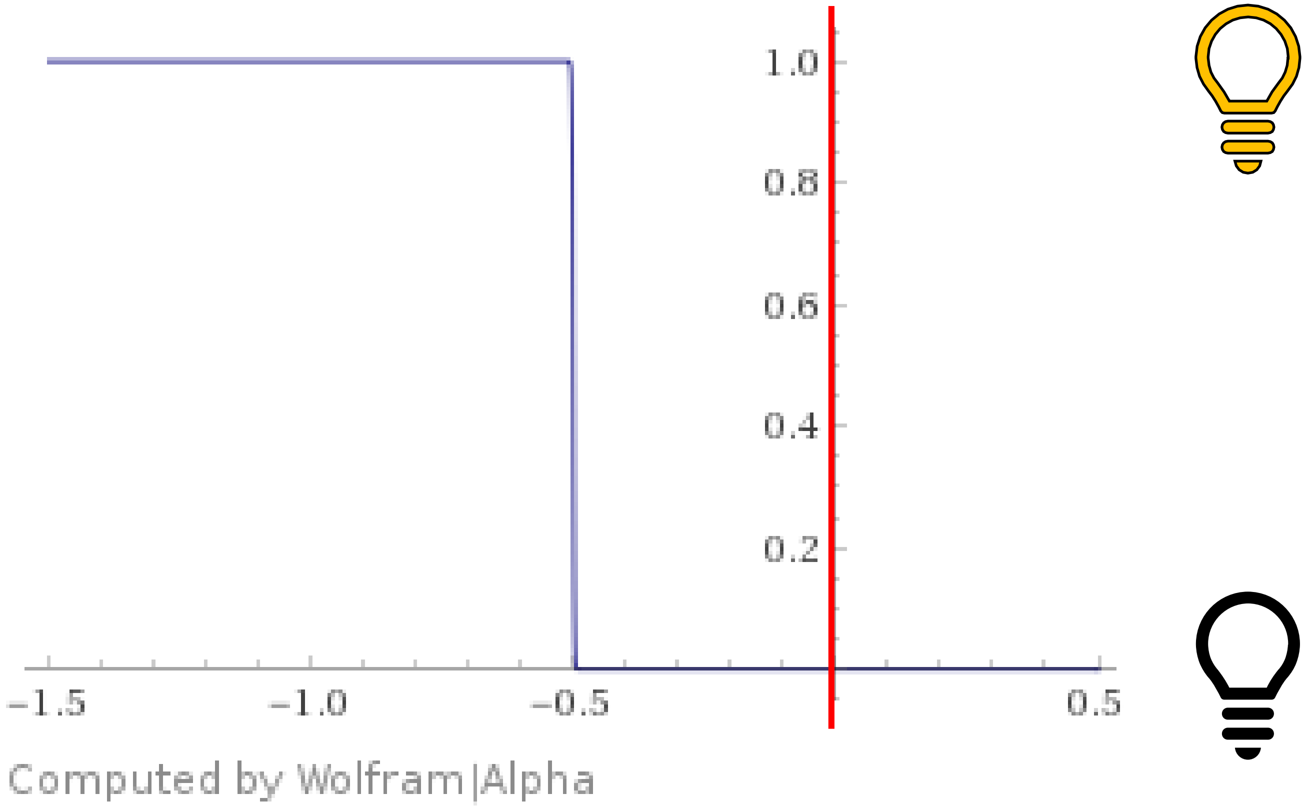
Leuchtet der Rest?

$$L_{Vk}(t+\Delta t) = 1 - \sigma_{1000,-0.5}\left(\sum_{Ul} W_{Vk,Ul} * \sigma_{35,0.6}\left(X_{Ul}(t)\right)\right)$$

Für Rest bei $\boldsymbol{Ul = A1}$

$$W_{Vk,Ul} \begin{cases} -0.5 & \text{Wenn } V = U \text{ und } k \neq l \\ -0.5 & \text{Wenn } V \neq U \text{ und } k = l \\ -v * dist(V,U) & \text{Wenn } V \neq U \text{ und } |k-l| = 1 \\ \boxed{0 \quad \text{Ansonsten}} & \end{cases}$$

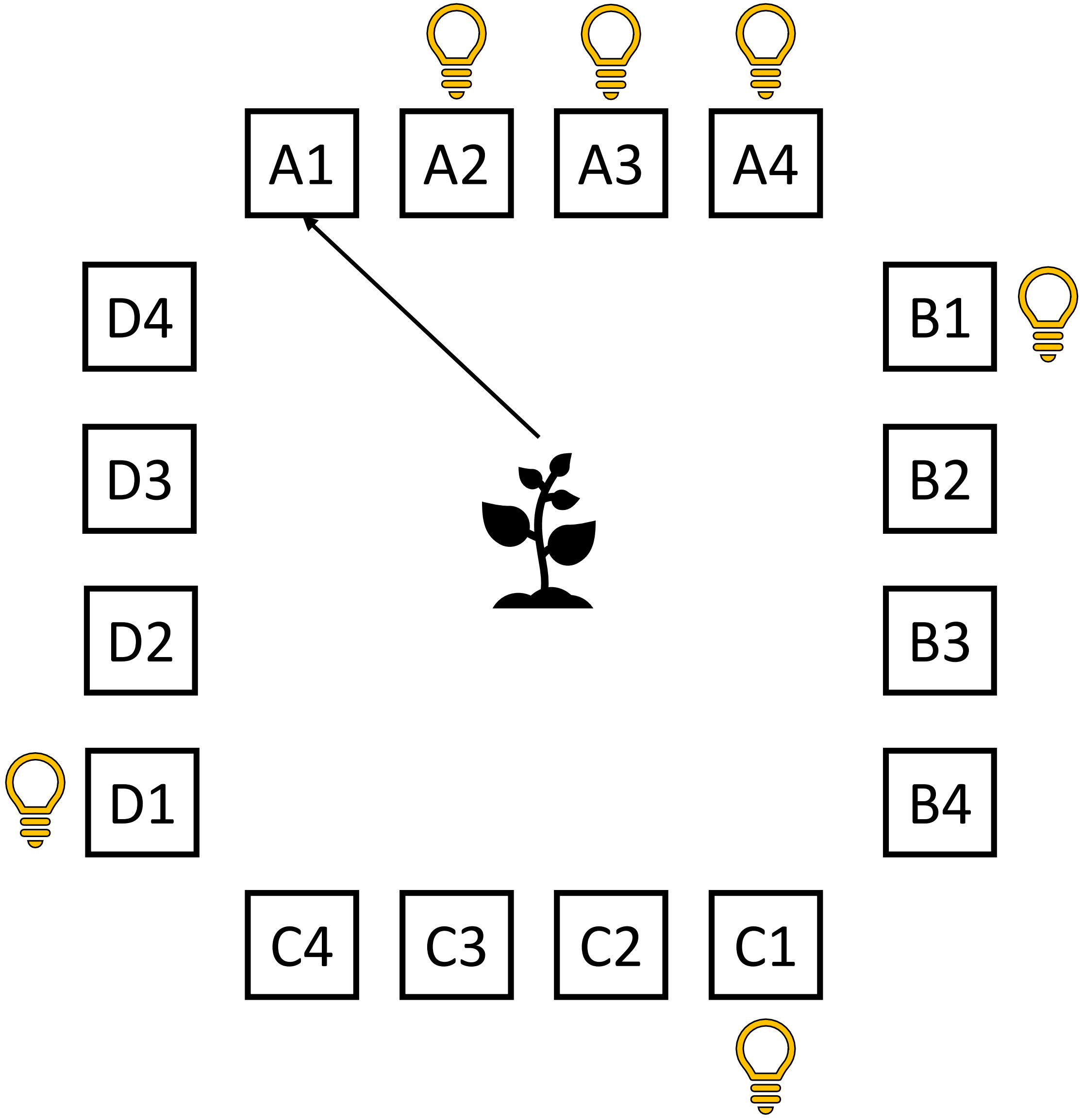
$$L_{Vk}(t+\Delta t) = 1 - \sigma_{1000,-0.5}\left(\sum_{Ul} \underbrace{W_{Vk,Ul}}_{0} * \underbrace{\sigma_{35,0.6}\left(X_{Ul}(t)\right)}_{1}\right)$$



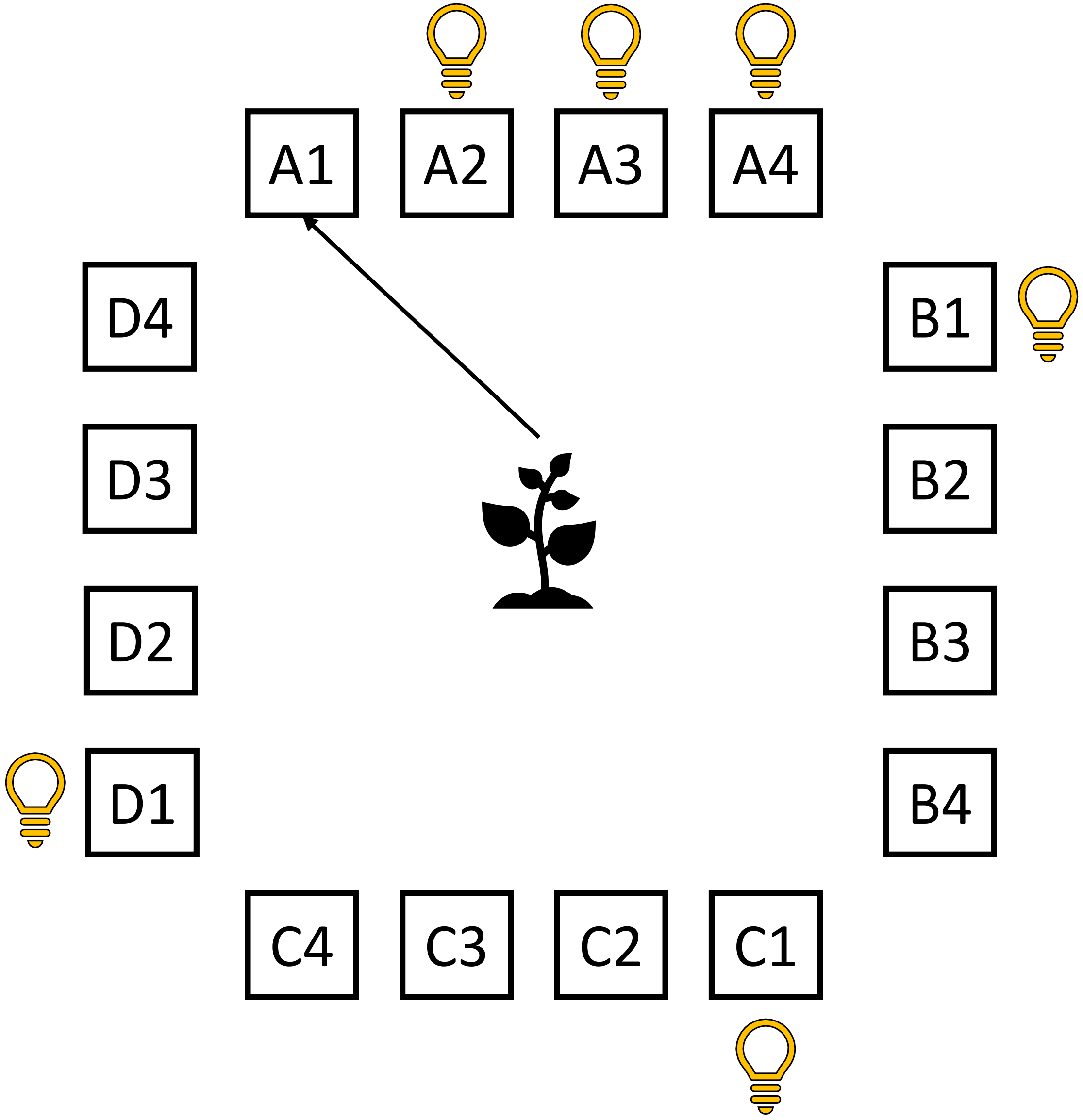
Nachbar oder Gegenüber belegt

Nachbar und Gegenüber frei

$$L_{Vk}(t+\Delta t) = 1 - \sigma_{1000,-0.5}\left(\sum_{Ul} W_{Vk,Ul} * \sigma_{35,0.6}\big(X_{Ul}(t)\big)\right)$$

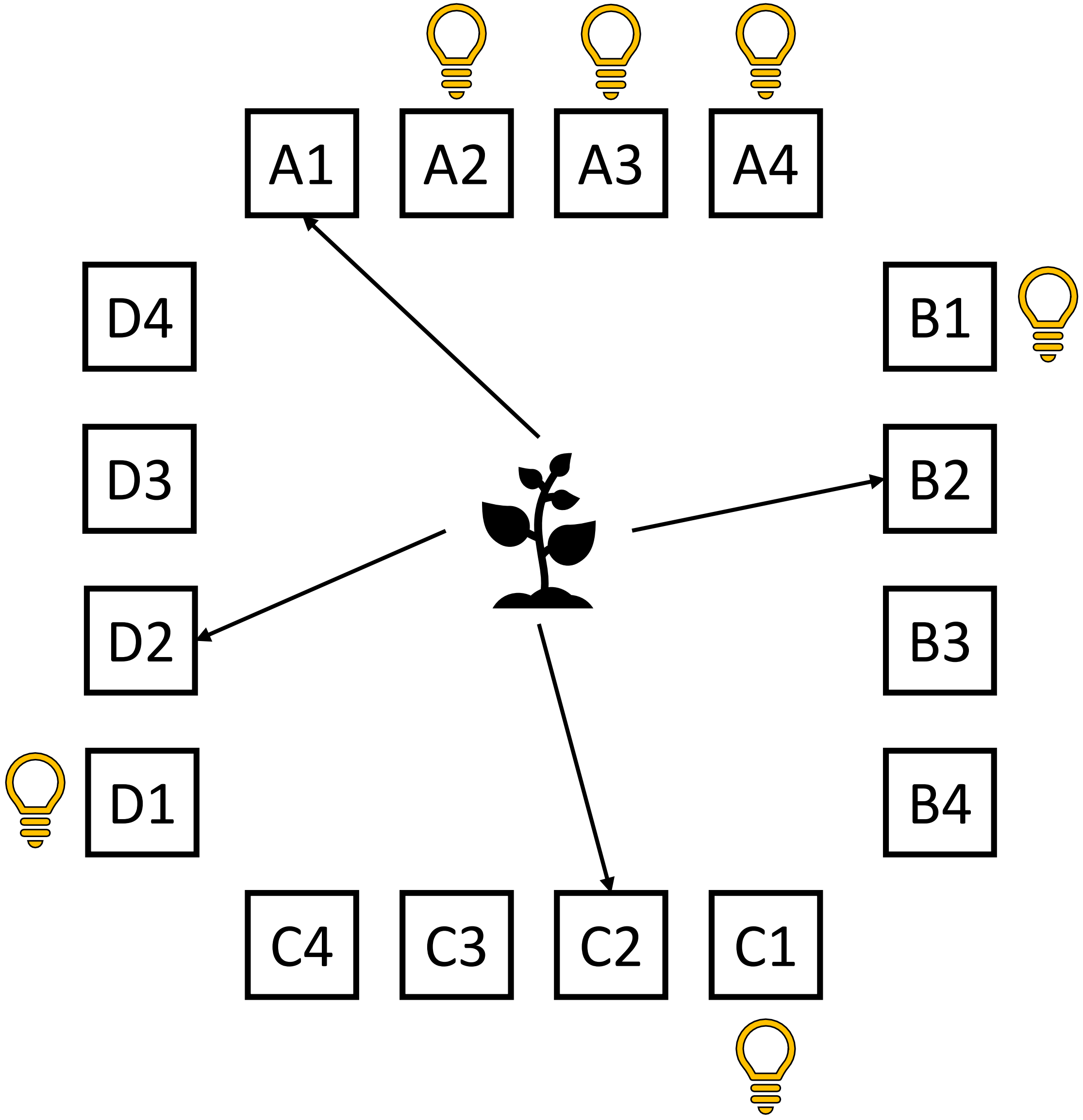


$$L_{Vk}(t + \Delta t) = 1 - \sigma_{1000,-0.5}\left(\sum_{Ul} W_{Vk,Ul} * \sigma_{35,0.6}\big(X_{Ul}(t)\big)\right)$$



Welcher Ort wird als nächstes besucht?

$$L_{Vk}(t+\Delta t) = 1 - \sigma_{1000,-0.5}\left(\sum_{Ul} W_{Vk,Ul} * \sigma_{35,0.6}\left(X_{Ul}(t)\right)\right)$$

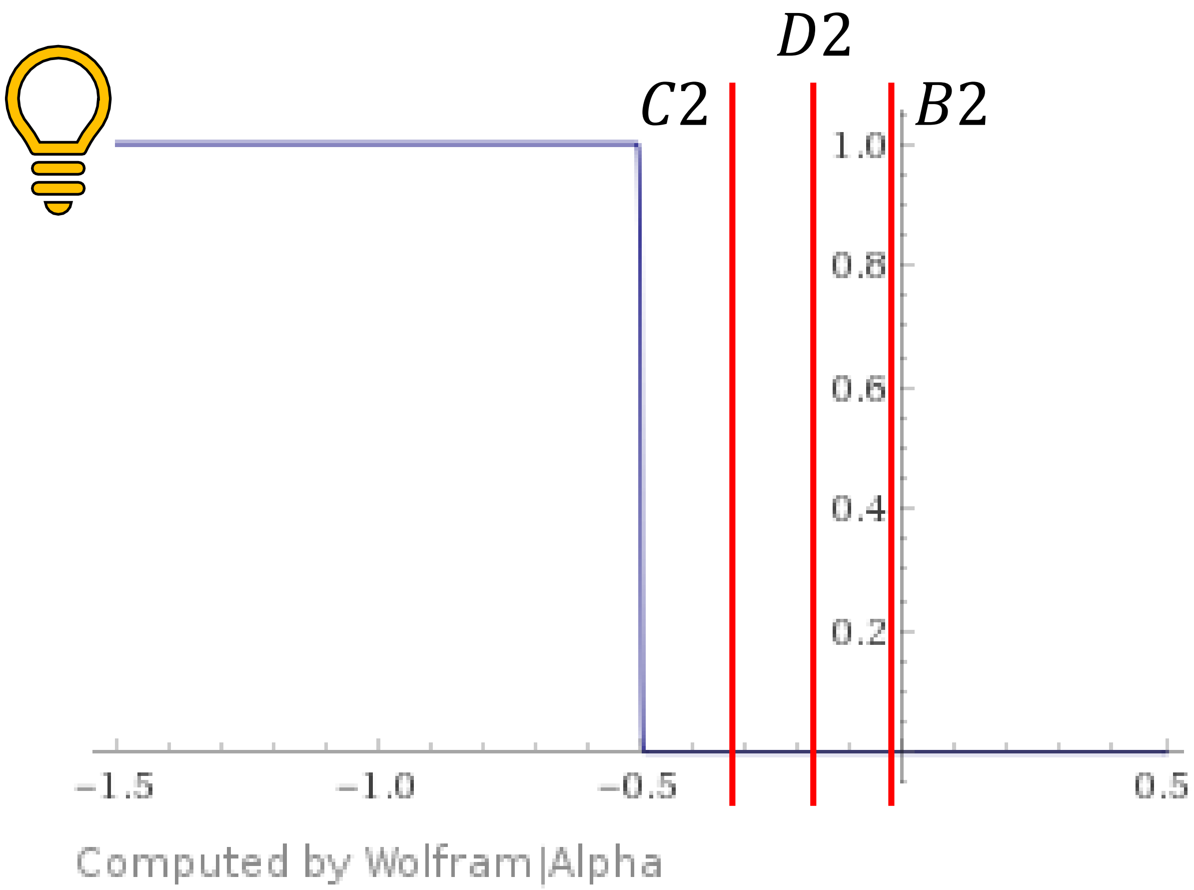


Welcher Ort wird als nächstes besucht?

B2, C2 oder D2?

$$L_{Vk}(t+\Delta t) = 1 - \sigma_{1000,-0.5}\left(\sum_{Ul} \underbrace{W_{Vk,Ul}} * \underbrace{\sigma_{35,0.6}\left(X_{Ul}(t)\right)}_{1}\right)$$

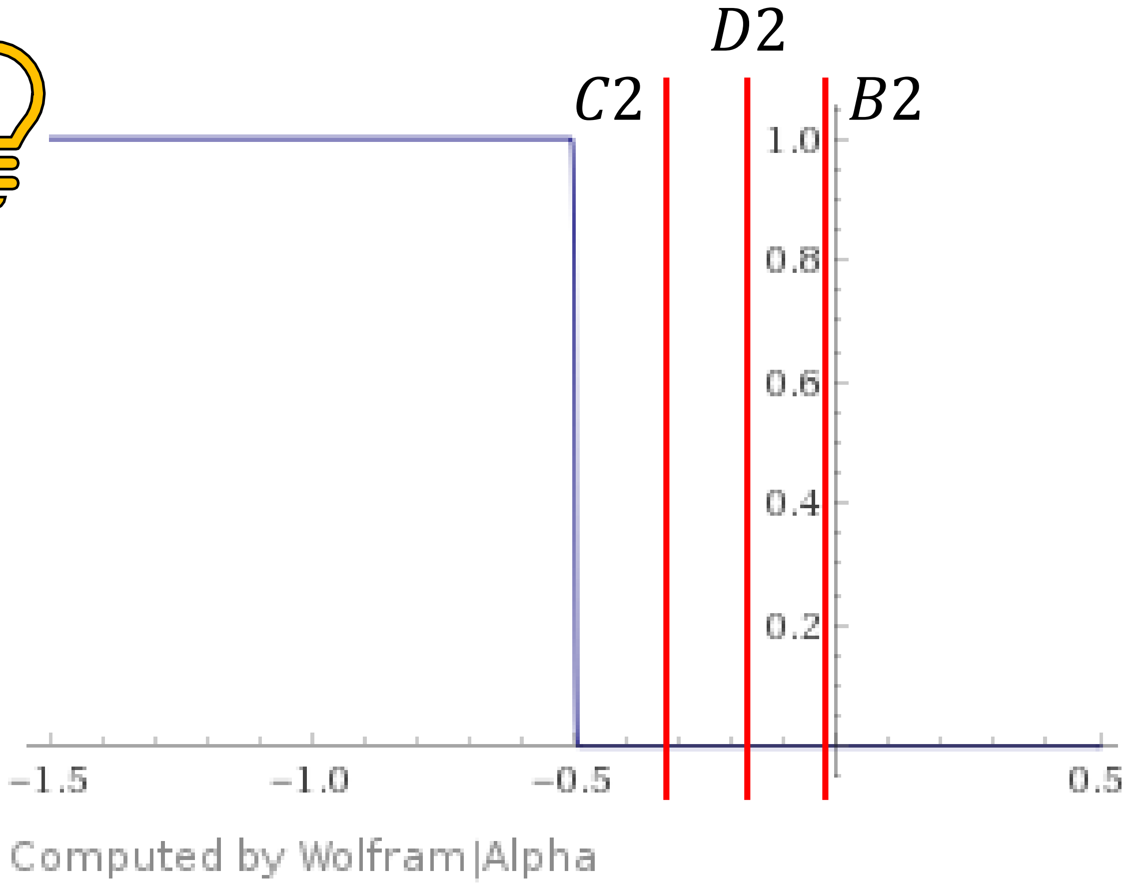
$$W_{B2,A1} = -0.02475$$
$$W_{C2,A1} = -0.32175$$
$$W_{D2,A1} = -0.17325$$



$$L_{Vk}(t+\Delta t) = 1 - \sigma_{1000,-0.5}\left(\sum_{Ul} \underbrace{W_{Vk,Ul}} * \underbrace{\sigma_{35,0.6}\left(X_{Ul}(t)\right)}_{1}\right)$$

$$W_{B2,A1} = -0.02475$$
$$W_{C2,A1} = -0.32175$$
$$W_{D2,A1} = -0.17325$$

$$\boldsymbol{X_{B2,C2,D2} \rightarrow 1}$$



$$L_{Vk}(t+\Delta t) = 1 - \sigma_{1000,-0.5}\left(\sum_{Ul} W_{Vk,Ul} * \sigma_{35,0.6}\left(X_{Ul}(t)\right)\right)$$

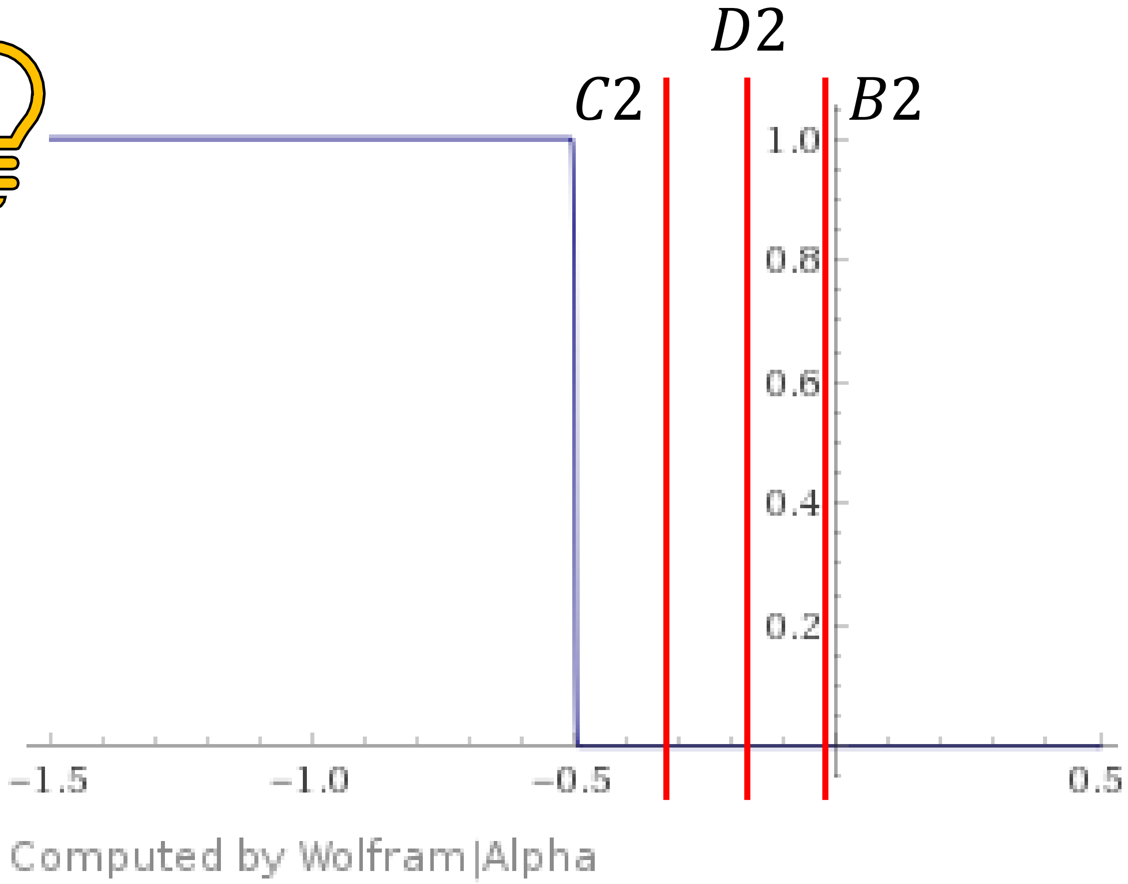
Für B2, C2 & D2 bei $\boldsymbol{Ul} \in \{\boldsymbol{B2}, \boldsymbol{C2}, \boldsymbol{D2}\}$

$$W_{Vk,Ul} \begin{cases} -0.5 & \text{Wenn } V = U \text{ und } k \neq l \\ \boxed{-0.5 \quad \text{Wenn } V \neq U \text{ und } k = l} & \\ -v * dist(V,U) & \text{Wenn } V \neq U \text{ und } |k-l| = 1 \\ 0 & \text{Ansonsten} \end{cases}$$

$$L_{Vk}(t+\Delta t) = 1 - \sigma_{1000,-0.5}\left(\sum_{Ul} \underbrace{W_{Vk,Ul}} * \underbrace{\sigma_{35,0.6}\left(X_{Ul}(t)\right)}_{1}\right)$$

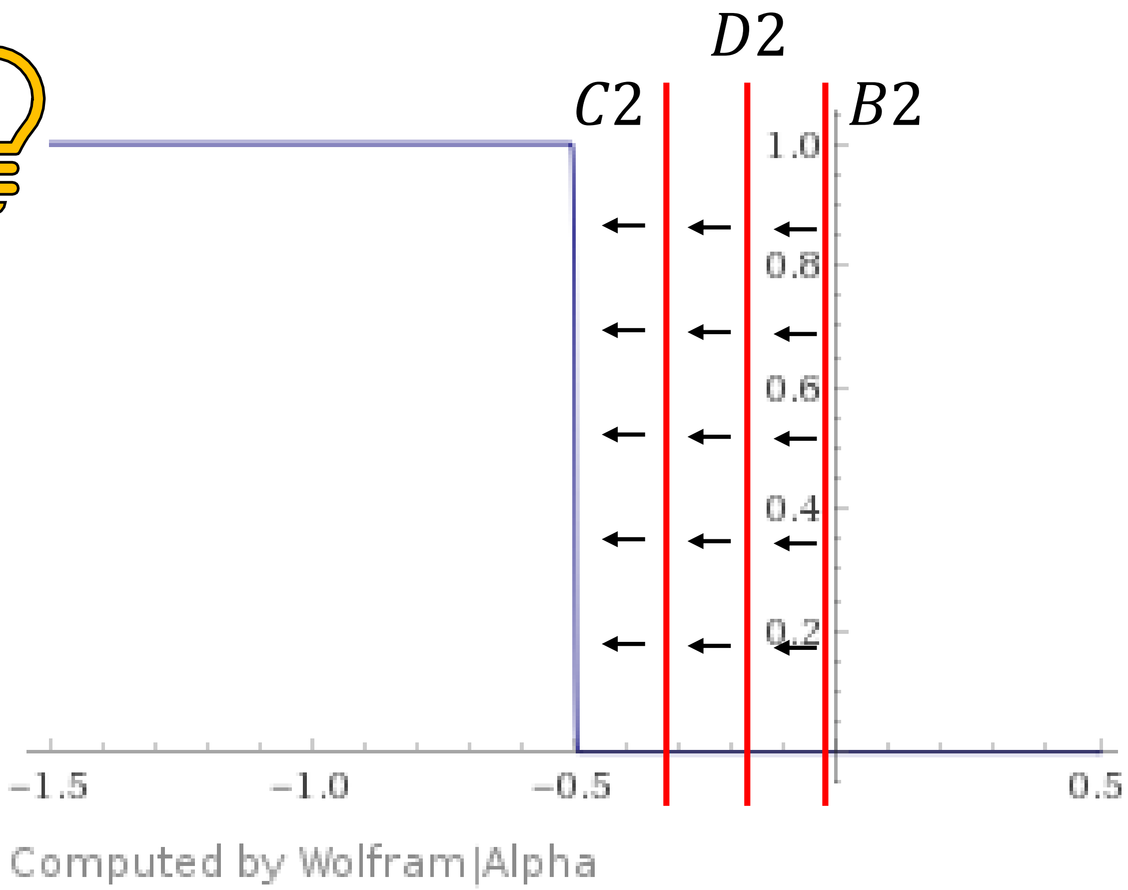
$$W_{B2,A1} = -0.02475$$
$$W_{C2,A1} = -0.32175$$
$$W_{D2,A1} = -0.17325$$

$\boldsymbol{X_{B2,C2,D2} \rightarrow 1}$ **mit** $\boldsymbol{W_{B2,C2,D2} = -0.5}$



$$L_{Vk}(t+\Delta t) = 1 - \sigma_{1000,-0.5}\left(\sum_{Ul} \underbrace{W_{Vk,Ul}} * \underbrace{\sigma_{35,0.6}\big(X_{Ul}(t)\big)}_{1}\right)$$

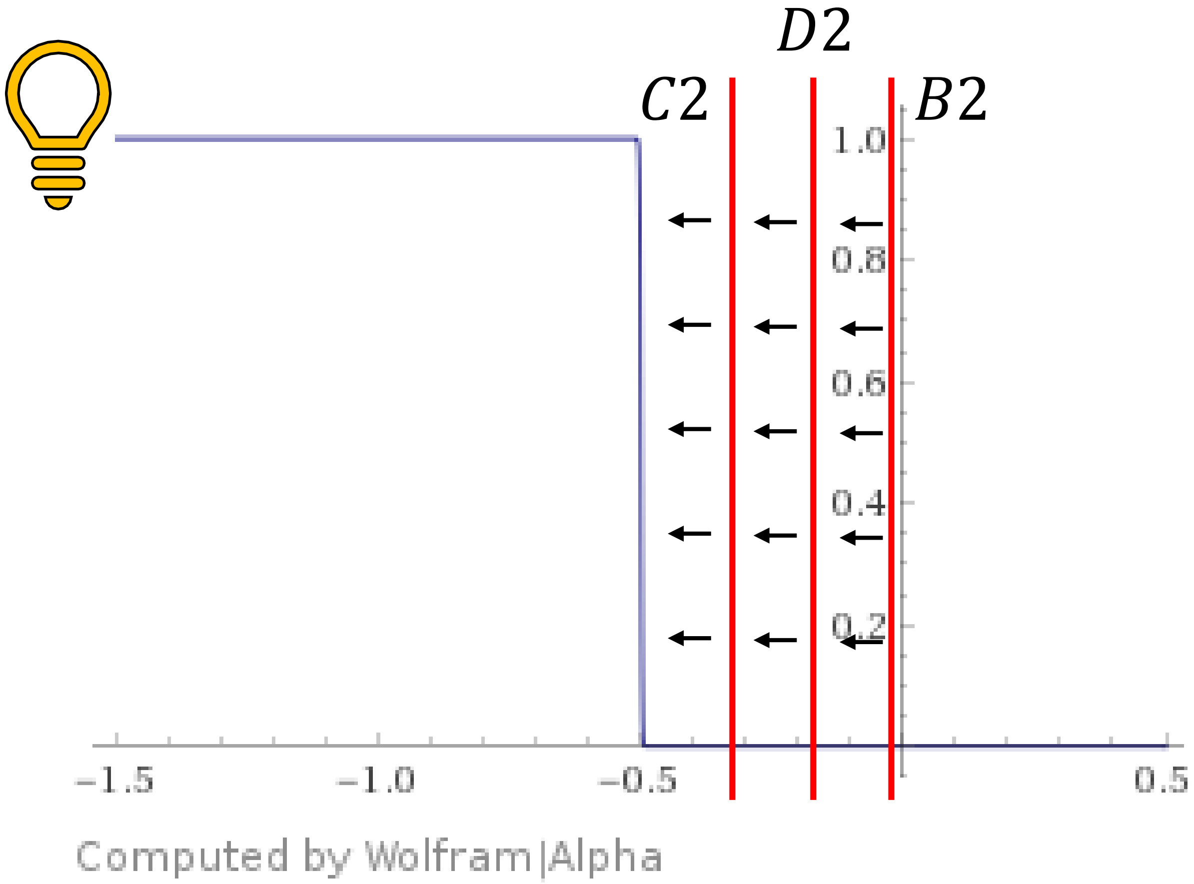
$$W_{B2,A1} = -0.02475$$
$$W_{C2,A1} = -0.32175$$
$$W_{D2,A1} = -0.17325$$



$\boldsymbol{X_{B2,C2,D2} \rightarrow 1}$ **mit** $\boldsymbol{W_{B2,C2,D2} = -0.5}$

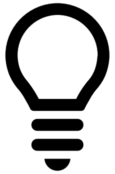
$$L_{Vk}(t+\Delta t) = 1 - \sigma_{1000,-0.5}\left(\sum_{Ul} \underbrace{W_{Vk,Ul}} * \underbrace{\sigma_{35,0.6}\left(X_{Ul}(t)\right)}_{1}\right)$$

$W_{B2,A1} = -0.02475$
$W_{C2,A1} = -0.32175$
$W_{D2,A1} = -0.17325$



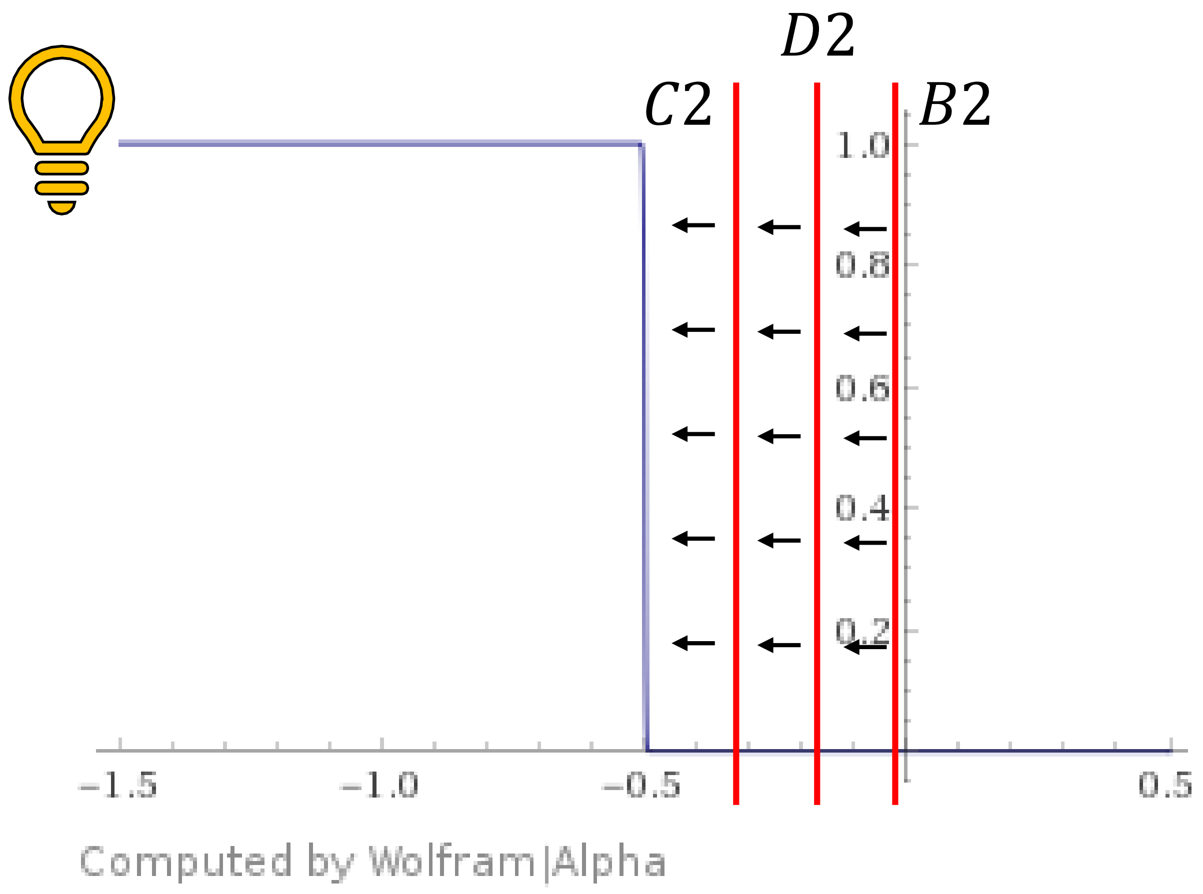
$\boldsymbol{X_{B2,C2,D2}} \rightarrow$ **1 mit** $\boldsymbol{W_{B2,C2,D2} = -0.5}$

→ C2 leuchtet



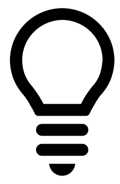
$$L_{Vk}(t+\Delta t) = 1 - \sigma_{1000,-0.5}\left(\sum_{Ul} \underbrace{W_{Vk,Ul}} * \underbrace{\sigma_{35,0.6}\left(X_{Ul}(t)\right)}_{1}\right)$$

$$W_{B2,A1} = -0.02475$$
$$W_{C2,A1} = -0.32175$$
$$W_{D2,A1} = -0.17325$$

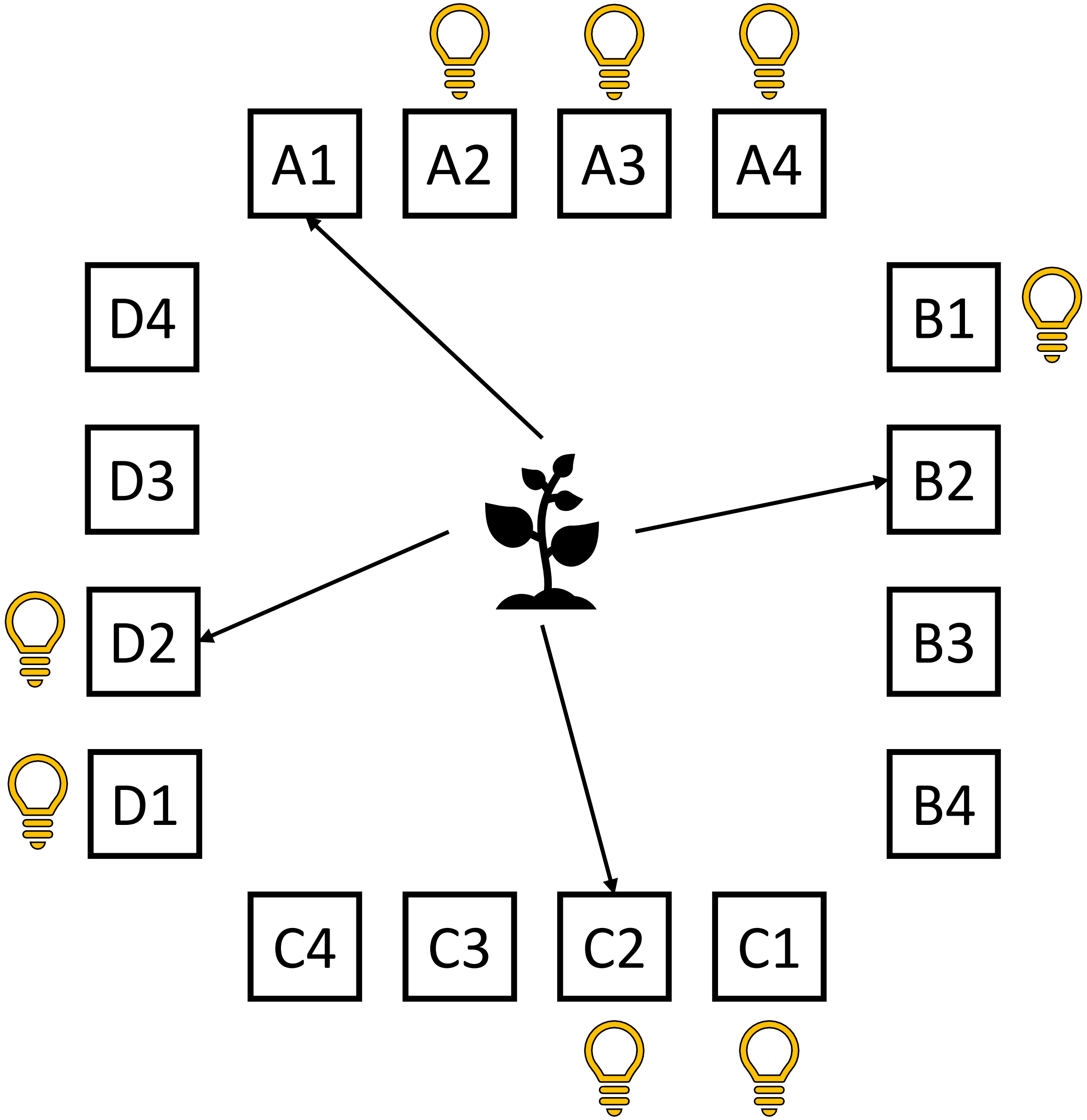


$\boldsymbol{X_{B2,C2,D2} \rightarrow 1}$ **mit** $\boldsymbol{W_{B2,C2,D2} = -0.5}$

→ C2 leuchtet
→ D2 leuchtet



$$L_{Vk}(t+\Delta t) = 1 - \sigma_{1000,-0.5}\left(\sum_{Ul} W_{Vk,Ul} * \sigma_{35,0.6}\left(X_{Ul}(t)\right)\right)$$

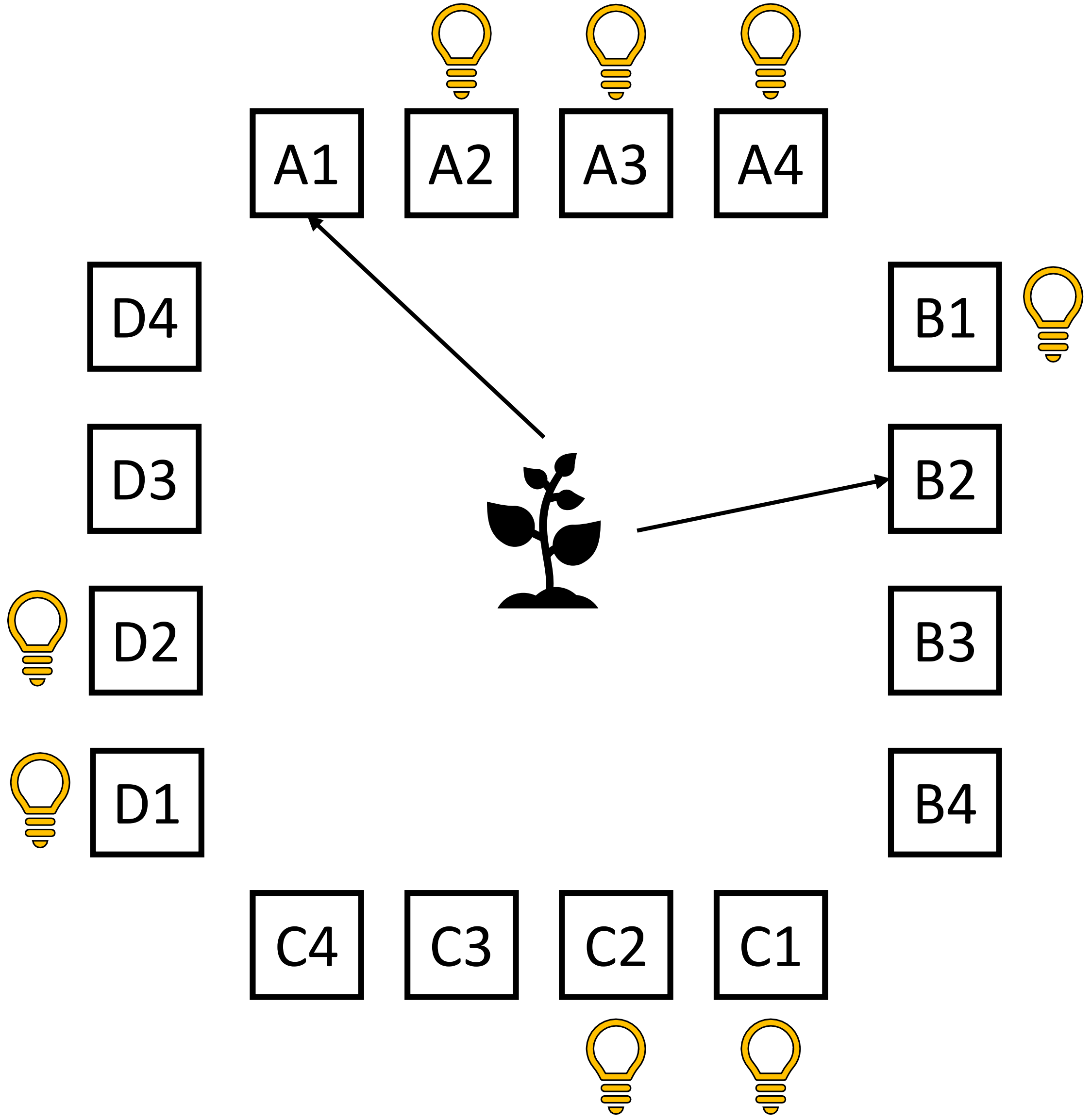


Welcher Ort wird als nächstes besucht?

B2, C2 oder D2?

→ C2 & D2 leuchten

$$L_{Vk}(t+\Delta t) = 1 - \sigma_{1000,-0.5}\left(\sum_{Ul} W_{Vk,Ul} * \sigma_{35,0.6}\big(X_{Ul}(t)\big)\right)$$

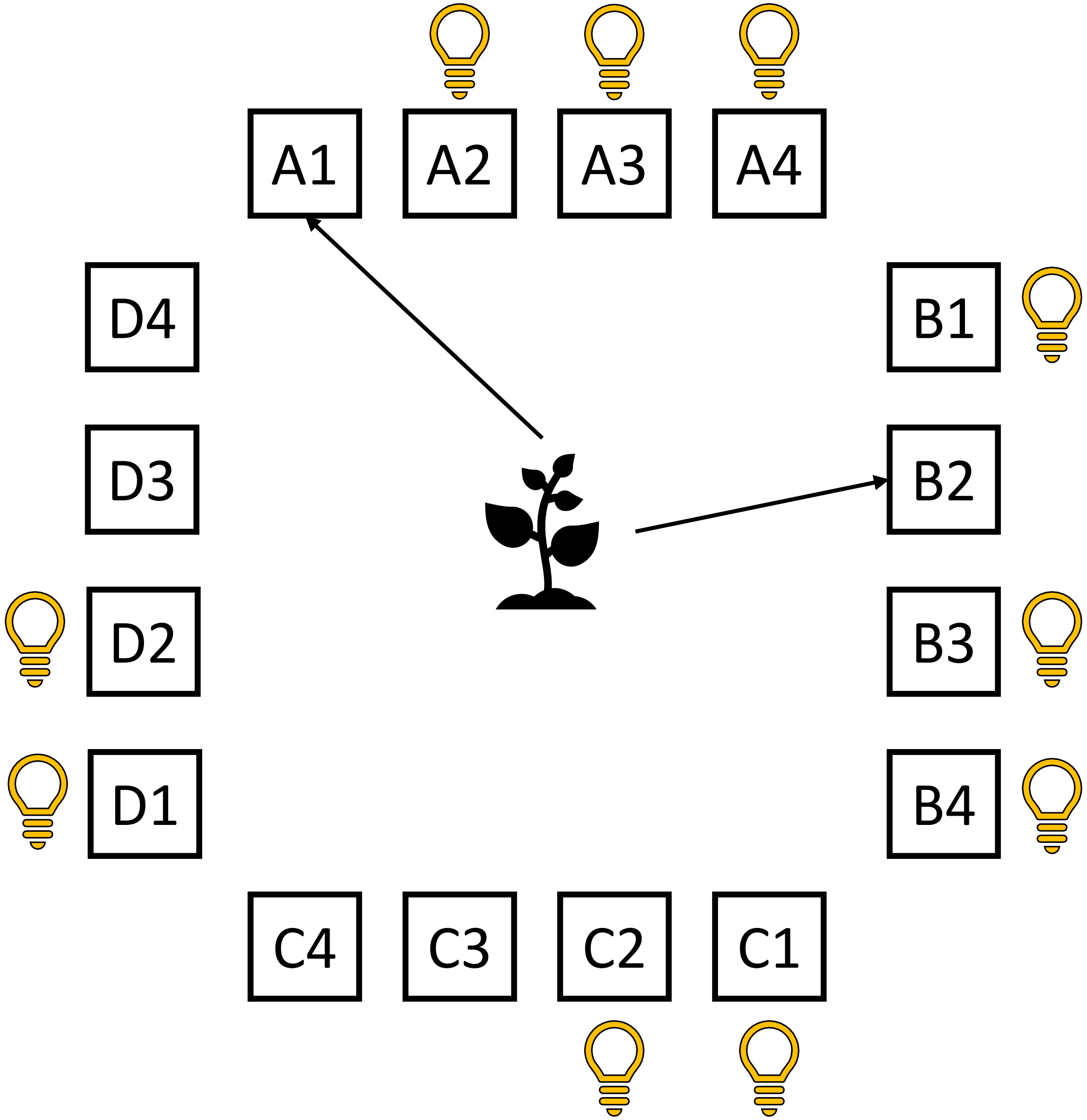


Welcher Ort wird als nächstes besucht?

B2, C2 oder D2?

→ C2 & D2 leuchten

$$L_{Vk}(t+\Delta t) = 1 - \sigma_{1000,-0.5}\left(\sum_{Ul} W_{Vk,Ul} * \sigma_{35,0.6}\left(X_{Ul}(t)\right)\right)$$

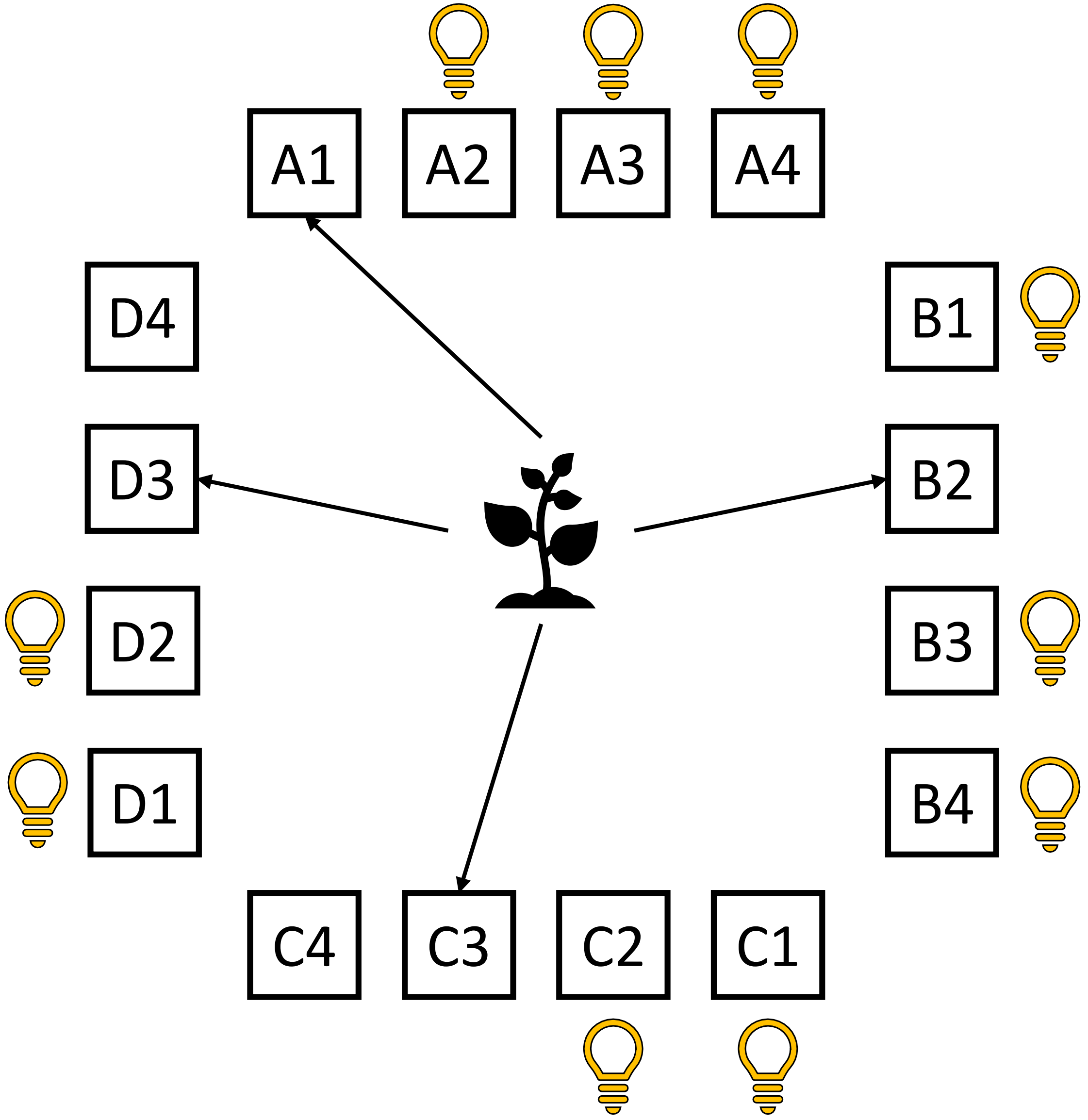


Welcher Ort wird als nächstes besucht?

B2, C2 oder D2?

→ C2 & D2 leuchten

$$L_{Vk}(t+\Delta t) = 1 - \sigma_{1000,-0.5}\left(\sum_{Ul} W_{Vk,Ul} * \sigma_{35,0.6}\left(X_{Ul}(t)\right)\right)$$



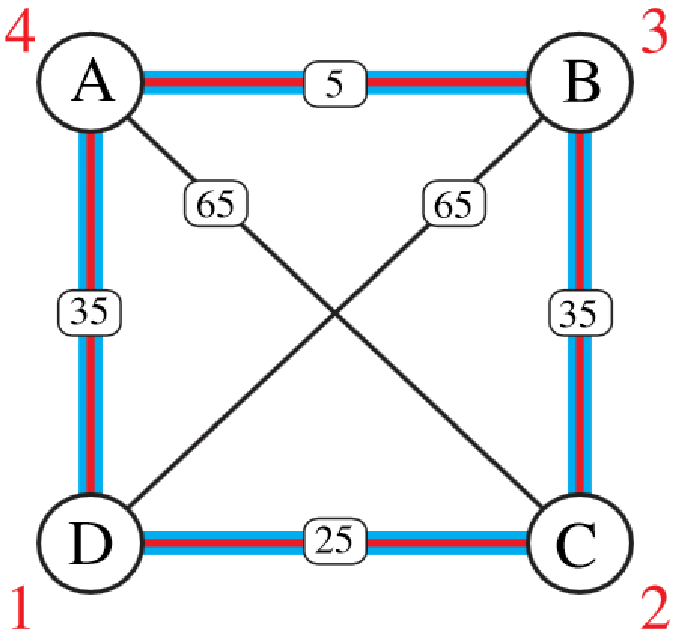
Welcher Ort wird als nächstes besucht?

C3 oder D3?

$$L_{Vk}(t+\Delta t) = 1 - \sigma_{1000,-0.5}\left(\sum_{Ul} W_{Vk,Ul} * \sigma_{35,0.6}\big(X_{Ul}(t)\big)\right)$$

$$-v * dist(V,U) \qquad n = 4 \rightarrow v = 0.00495$$

(a) $n = 4$

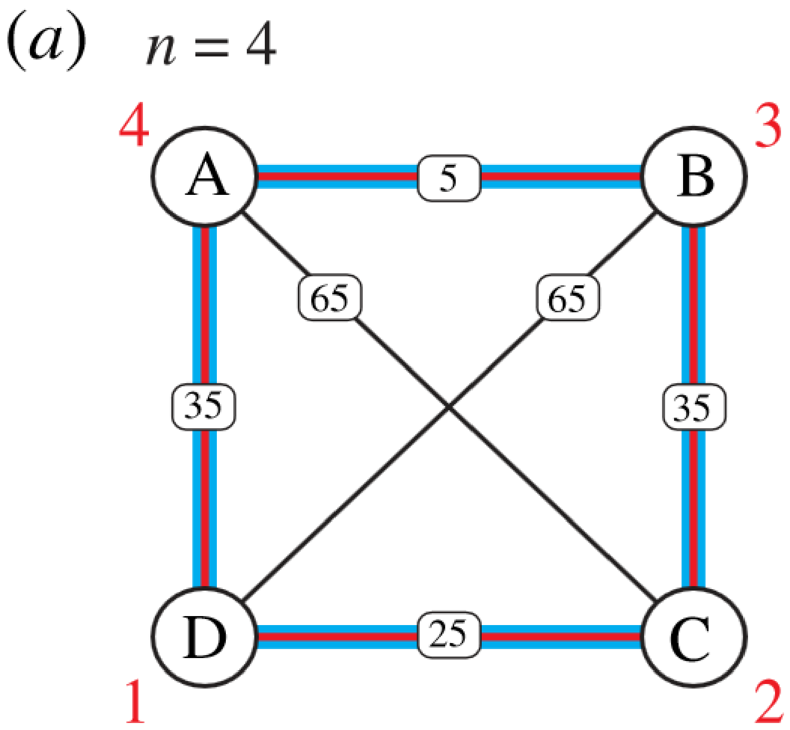


$W_{C3,B2}$

$W_{D3,B2}$

$$L_{Vk}(t+\Delta t) = 1 - \sigma_{1000,-0.5}\left(\sum_{Ul} W_{Vk,Ul} * \sigma_{35,0.6}\big(X_{Ul}(t)\big)\right)$$

$-v * dist(V,U)$ $\qquad$ $n = 4 \rightarrow v = 0.00495$

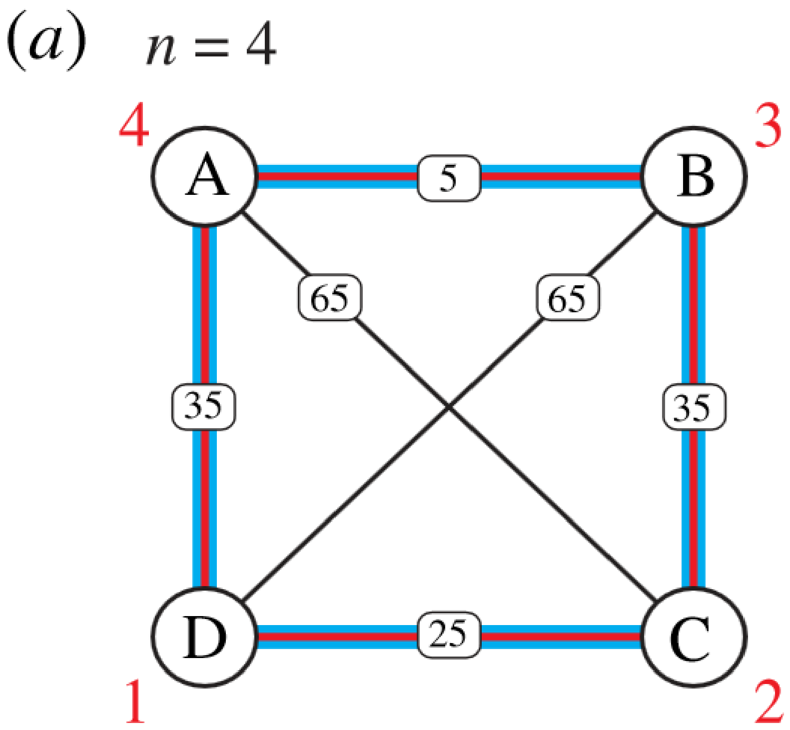


$$W_{C3,B2} = -0.00495 * 35 = -0.17325$$

$$W_{D3,B2} = -0.00495 * 65 = -0.32175$$

$$L_{Vk}(t+\Delta t) = 1 - \sigma_{1000,-0.5}\left(\sum_{Ul} W_{Vk,Ul} * \sigma_{35,0.6}\big(X_{Ul}(t)\big)\right)$$

$-v * dist(V,U)$ $\quad$ $n = 4 \rightarrow v = 0.00495$



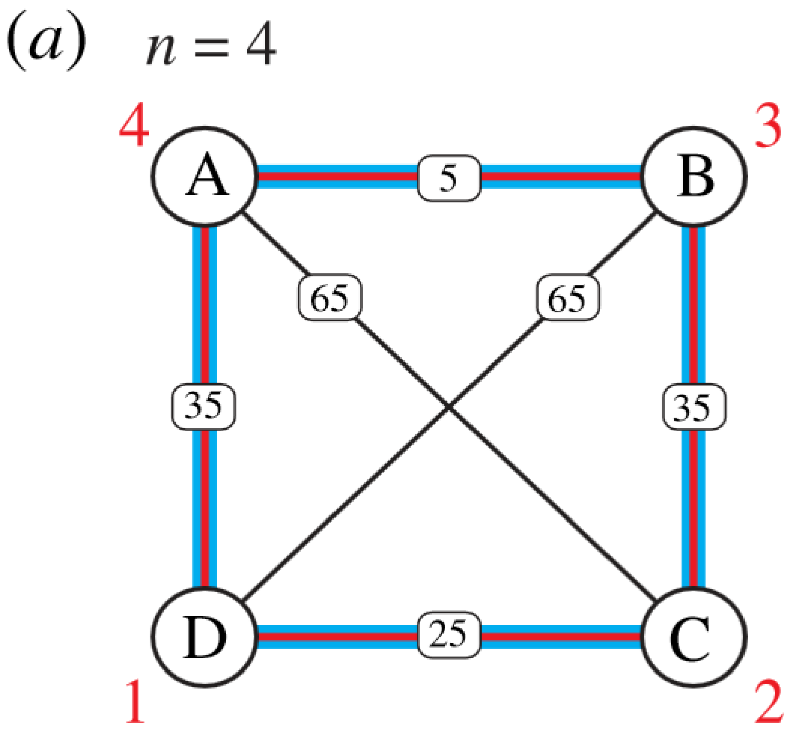
$$W_{C3,B2} = -0.00495 * 35 = -0.17325$$

$$W_{D3,B2} = -0.00495 * 65 = -0.32175$$

→ D3 wird zuerst leuchten

$$L_{Vk}(t+\Delta t) = 1 - \sigma_{1000,-0.5}\left(\sum_{Ul} W_{Vk,Ul} * \sigma_{35,0.6}\left(X_{Ul}(t)\right)\right)$$

$-v * dist(V,U)$ $\qquad$ $n = 4 \rightarrow v = 0.00495$



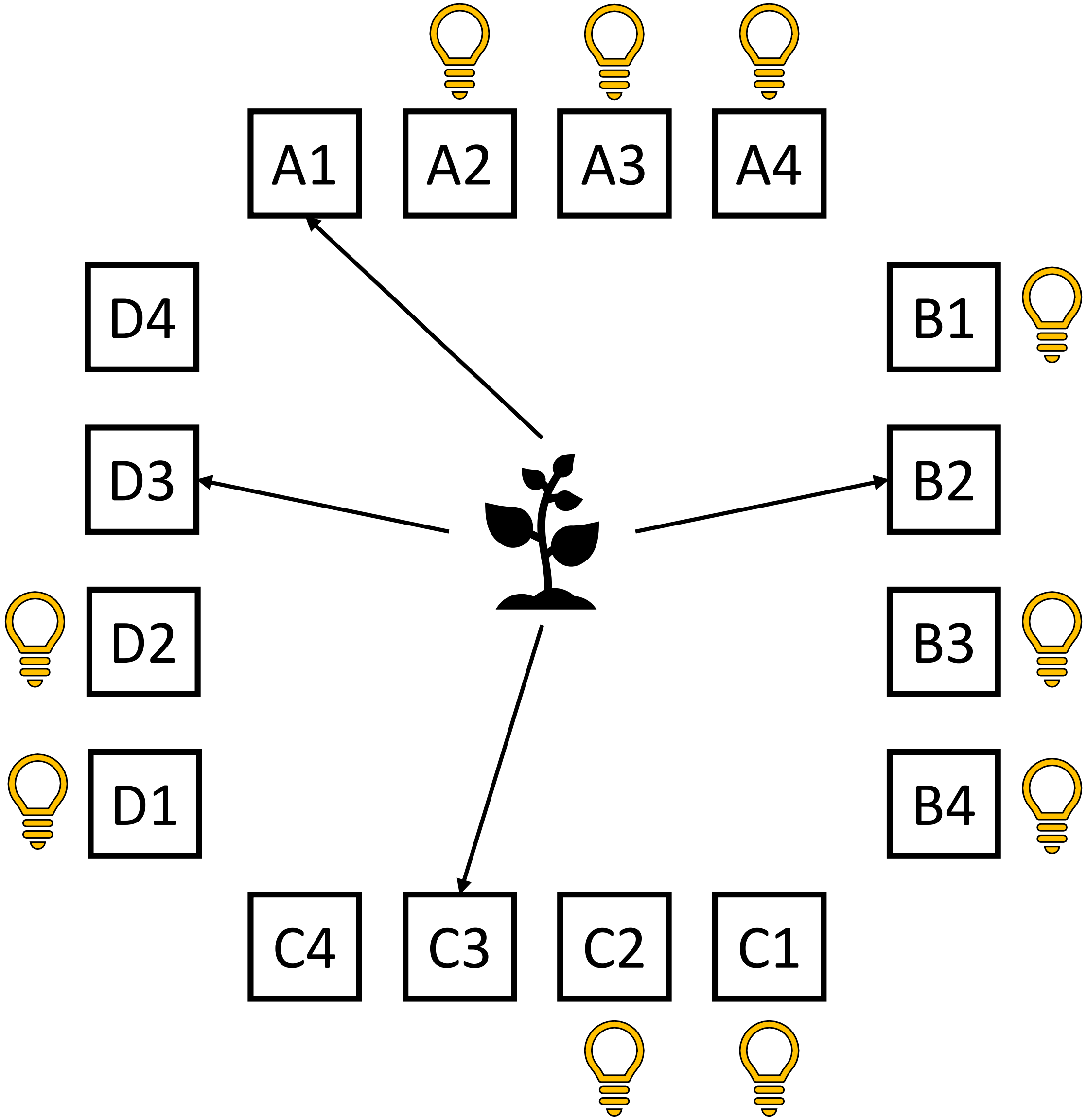
$W_{C3,B2} = -0.00495 * 35 = -0.17325$

$W_{D3,B2} = -0.00495 * 65 = -0.32175$

→ **D3 wird zuerst leuchten**

Merke:
Um so höher der Abstand,
um so schneller geht Lampe an!

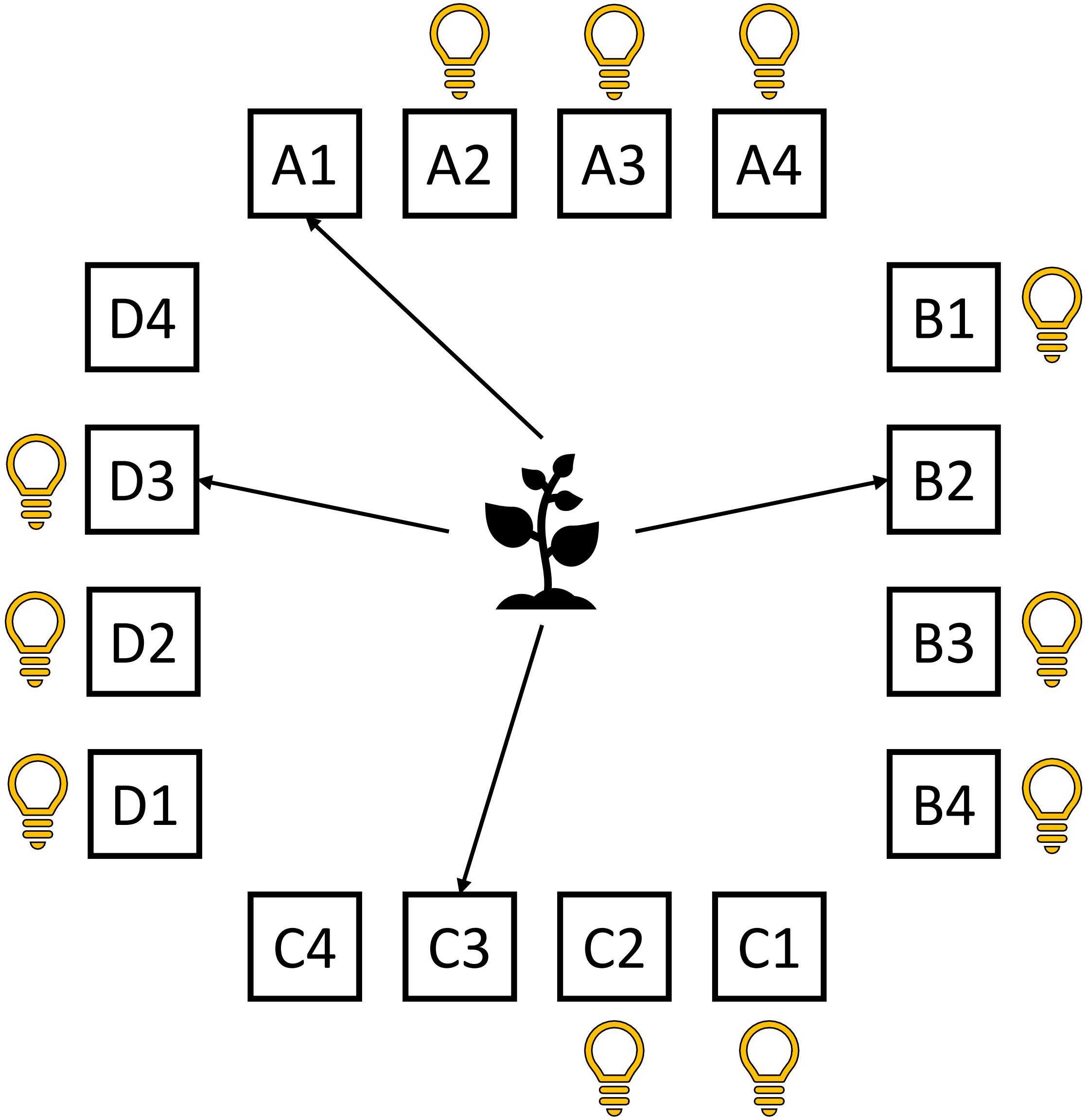
$$L_{Vk}(t+\Delta t) = 1 - \sigma_{1000,-0.5}\left(\sum_{Ul} W_{Vk,Ul} * \sigma_{35,0.6}\left(X_{Ul}(t)\right)\right)$$



Welcher Ort wird als nächstes besucht?

C3 oder D3?

$$L_{Vk}(t+\Delta t) = 1 - \sigma_{1000,-0.5}\left(\sum_{Ul} W_{Vk,Ul} * \sigma_{35,0.6}\left(X_{Ul}(t)\right)\right)$$

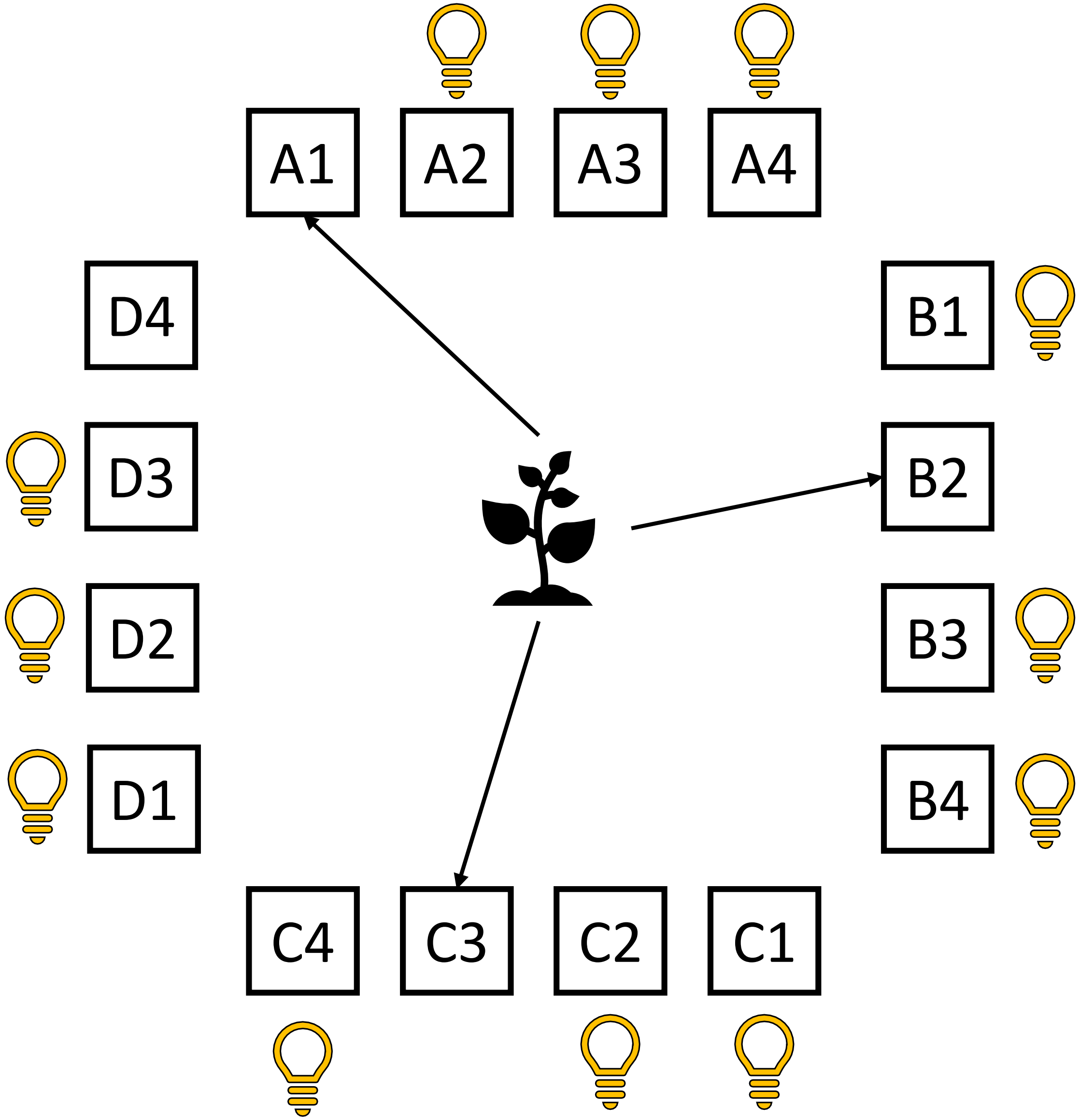


Welcher Ort wird als nächstes besucht?

C3 oder D3?

→ D3 leuchtet

$$L_{Vk}(t+\Delta t) = 1 - \sigma_{1000,-0.5}\left(\sum_{Ul} W_{Vk,Ul} * \sigma_{35,0.6}\left(X_{Ul}(t)\right)\right)$$

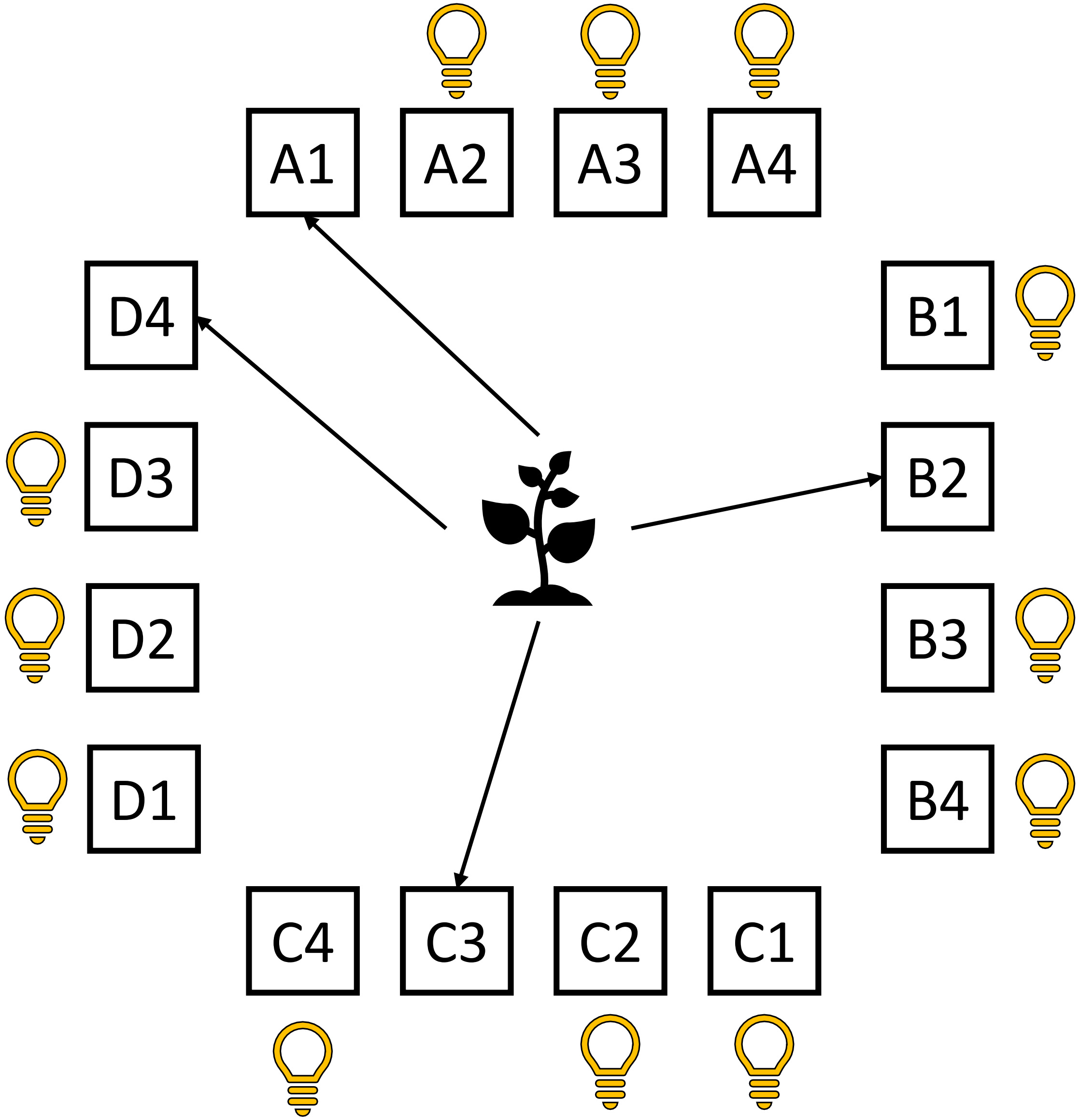


Welcher Ort wird als nächstes besucht?

C3 oder D3?

→ D3 leuchtet

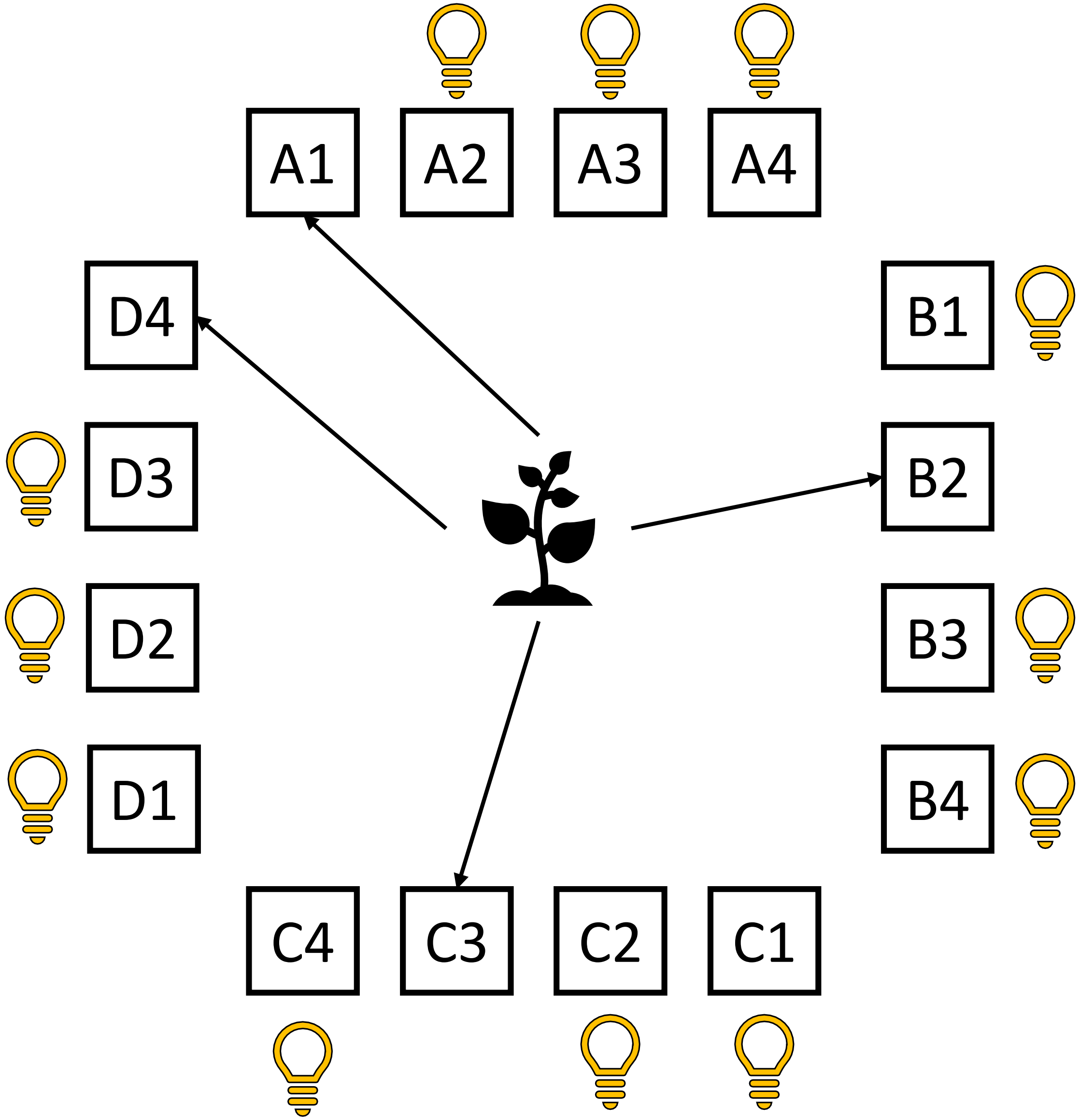
$$L_{Vk}(t+\Delta t) = 1 - \sigma_{1000,-0.5}\left(\sum_{Ul} W_{Vk,Ul} * \sigma_{35,0.6}\left(X_{Ul}(t)\right)\right)$$



D4 noch ohne Licht

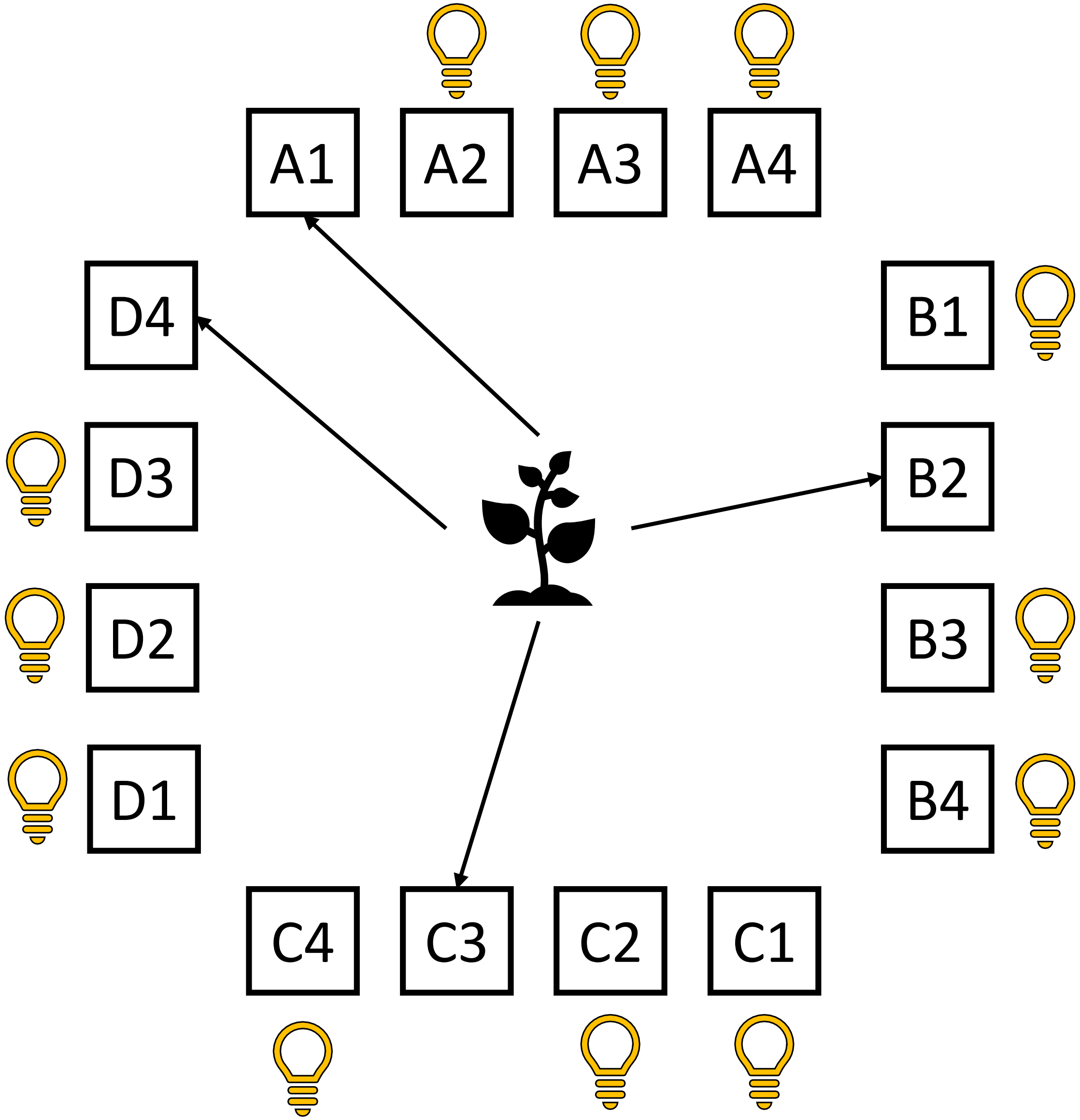
→ Besetzt

$$L_{Vk}(t+\Delta t) = 1 - \sigma_{1000,-0.5}\left(\sum_{Ul} W_{Vk,Ul} * \sigma_{35,0.6}\left(X_{Ul}(t)\right)\right)$$



Besetzt:
A1, B2, C3, D4

$$L_{Vk}(t+\Delta t) = 1 - \sigma_{1000,-0.5}\left(\sum_{Ul} W_{Vk,Ul} * \sigma_{35,0.6}\left(X_{Ul}(t)\right)\right)$$

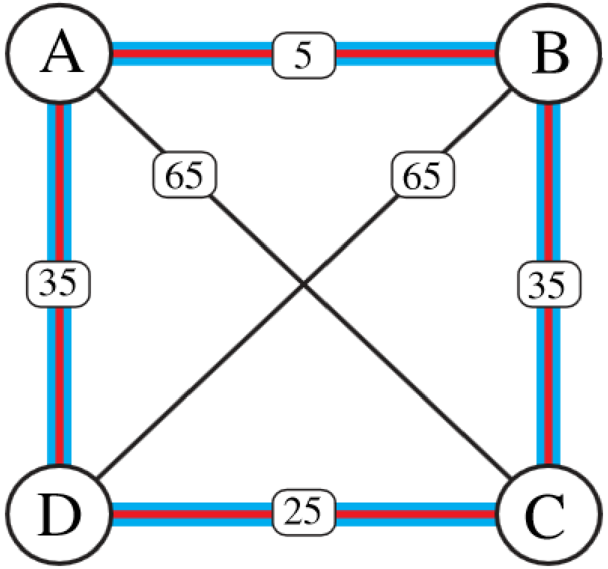


Besetzt:
A1, B2, C3, D4

Rundgang:
$\boldsymbol{A \rightarrow B \rightarrow C \rightarrow D \rightarrow A}$

$$L_{Vk}(t+\Delta t) = 1 - \sigma_{1000,-0.5}\left(\sum_{Ul} W_{Vk,Ul} * \sigma_{35,0.6}\left(X_{Ul}(t)\right)\right)$$

(a) $n = 4$

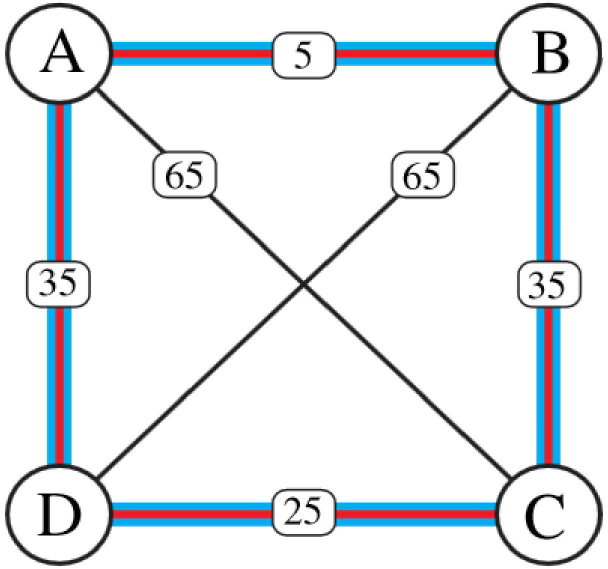


Rundgang:

$\boldsymbol{A \rightarrow B \rightarrow C \rightarrow D \rightarrow A}$

$$L_{Vk}(t+\Delta t) = 1 - \sigma_{1000,-0.5}\left(\sum\nolimits_{Ul} W_{Vk,Ul} * \sigma_{35,0.6}\left(X_{Ul}(t)\right)\right)$$

$(a)\quad n = 4$



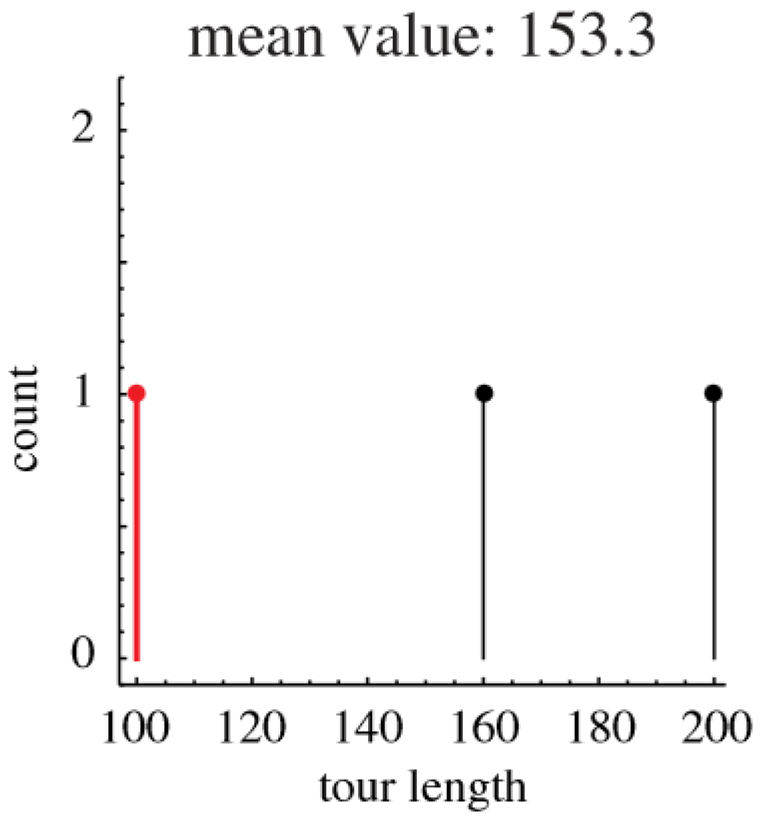
Rundgang:

$$\boldsymbol{A \to B \to C \to D \to A}$$

$$\mathbf{5 + 35 + 25 + 35}$$

$$\mathbf{= 100}$$

$$L_{Vk}(t+\Delta t) = 1 - \sigma_{1000,-0.5}\left(\sum_{Ul} W_{Vk,Ul} * \sigma_{35,0.6}\left(X_{Ul}(t)\right)\right)$$



Rundgang:

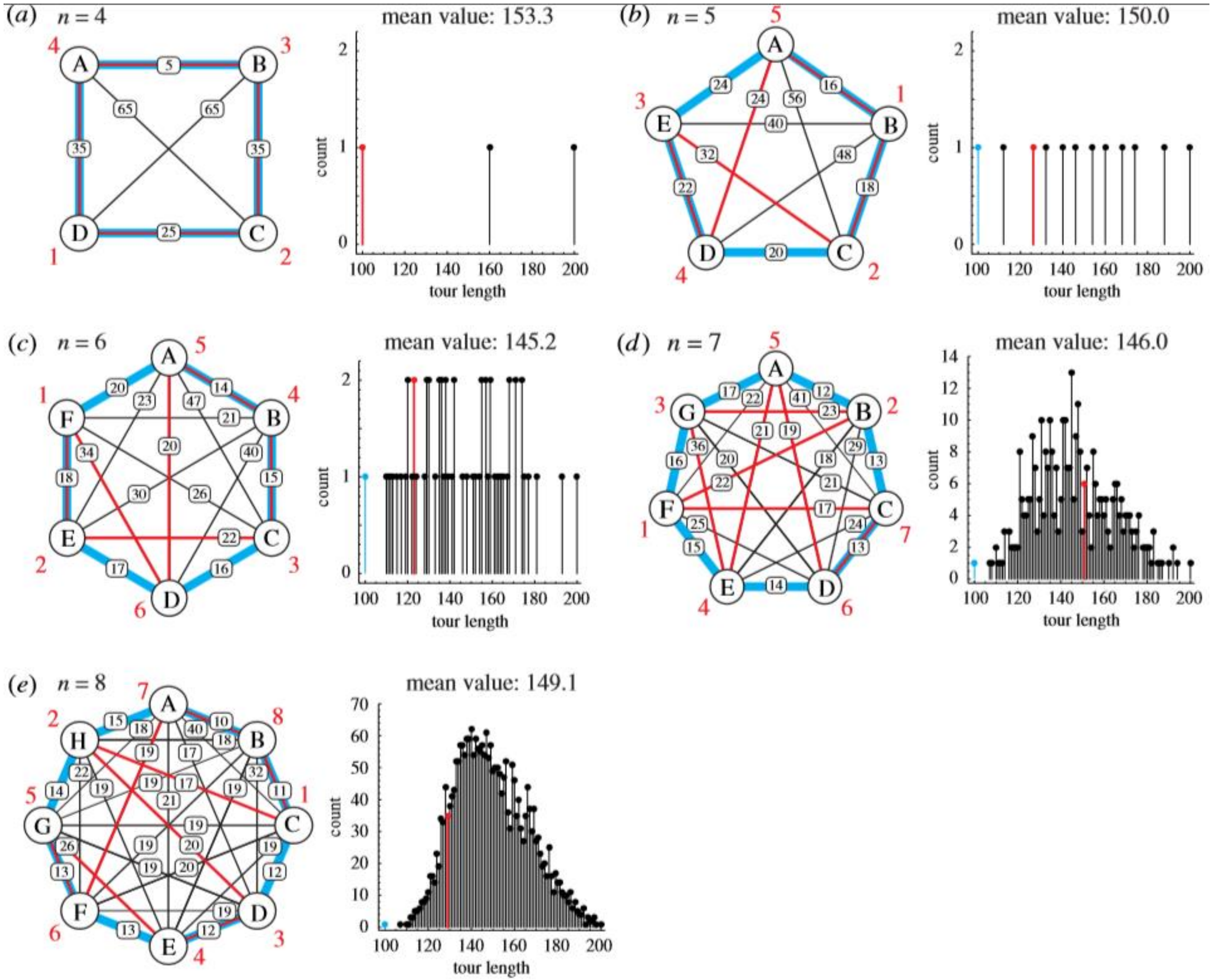
$$\boldsymbol{A \to B \to C \to D \to A}$$

$$\mathbf{5 + 35 + 25 + 35}$$

$$\mathbf{= 100}$$

→ Idealer Weg gefunden

Resultate


(a) n = 4
mean value: 153.3
(b) n = 5
mean value: 150.0
(c) n = 6
mean value: 145.2
(d) n = 7
mean value: 146.0
(e) n = 8
mean value: 149.1
count
tour length

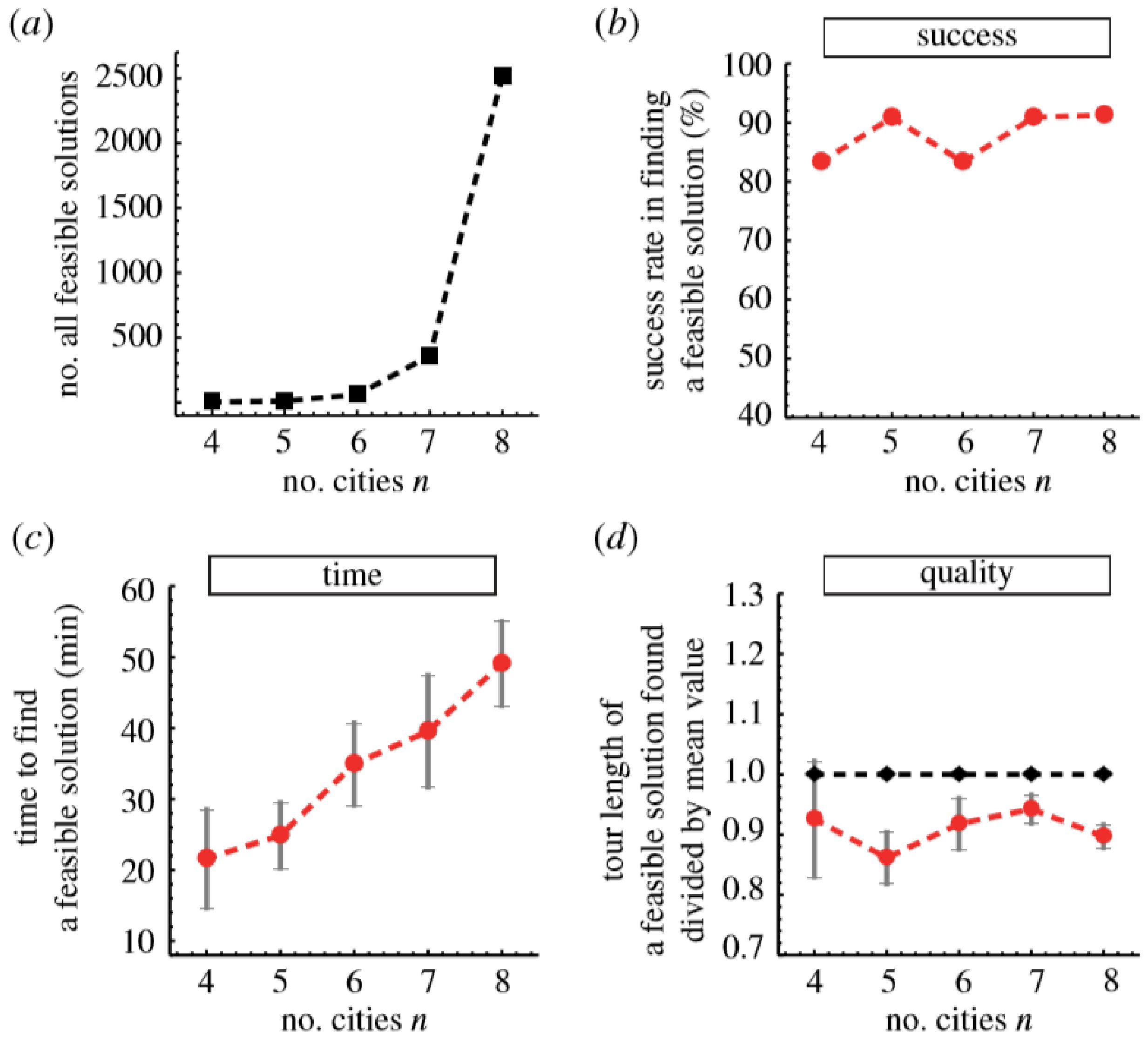
Resultate

n	4	5	6	7	8
mean tour length L_{mean} (known in advance)	153.3	150.0	145.2	146.0	149.1
number of experimental trials T	12	11	12	11	23
best tour length (found in experiment)	100	112	100	121	117
worst tour length (found in experiment)	200	168	174	151	165
Av. tour length L_{exp} (found in experiment)	142.0	129.2	133.3	137.6	133.8
L_{exp}/L_{mean}	0.926	0.861	0.918	0.942	0.897
top quality (%)	(33.3)	(25)	(33.3)	(37.5)	(20.7)

Resultate

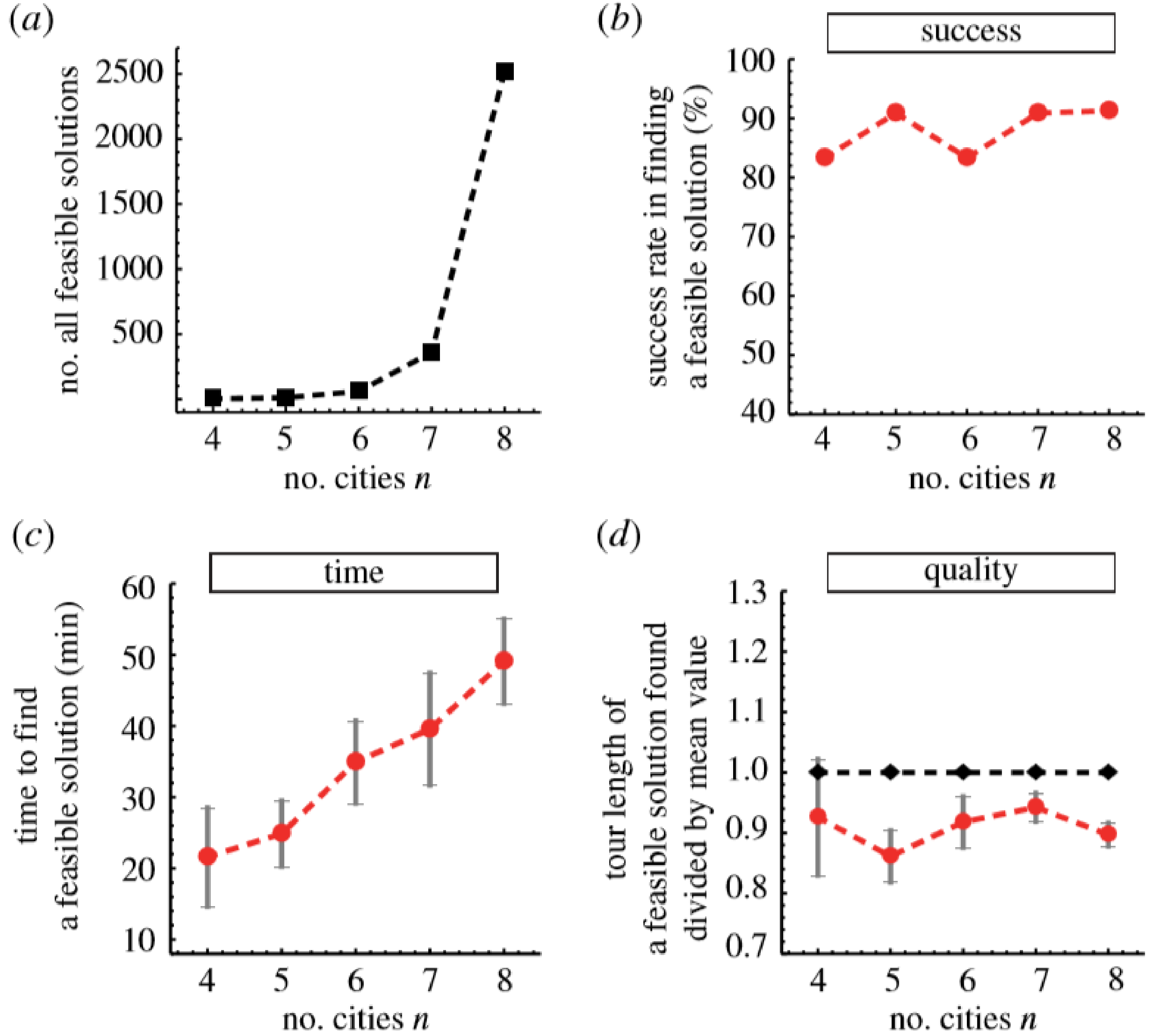
n	4	5	6	7	8
number of successful trials S (succeeded in finding a feasible solution)	10	10	10	10	21
success rate S/T (%)	83.3	90.9	83.3	90.9	91.3
Av. search time (min)	21.6	24.9	34.9	39.6	45.9

Resultate



(a)
no. all feasible solutions
2500
2000
1500
1000
500
4
5
6
7
8
no. cities n
(b)
success
success rate in finding a feasible solution (%)
100
90
80
70
60
50
40
4
5
6
7
8
no. cities n
(c)
time
time to find a feasible solution (min)
60
50
40
30
20
10
4
5
6
7
8
no. cities n
(d)
quality
tour length of a feasible solution found divided by mean value
1.3
1.2
1.1
1.0
0.9
0.8
0.7
4
5
6
7
8
no. cities n

Resultate



(a)
no. all feasible solutions
2500
2000
1500
1000
500
4
5
6
7
8
no. cities n
(b)
success
success rate in finding a feasible solution (%)
100
90
80
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60
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5
6
7
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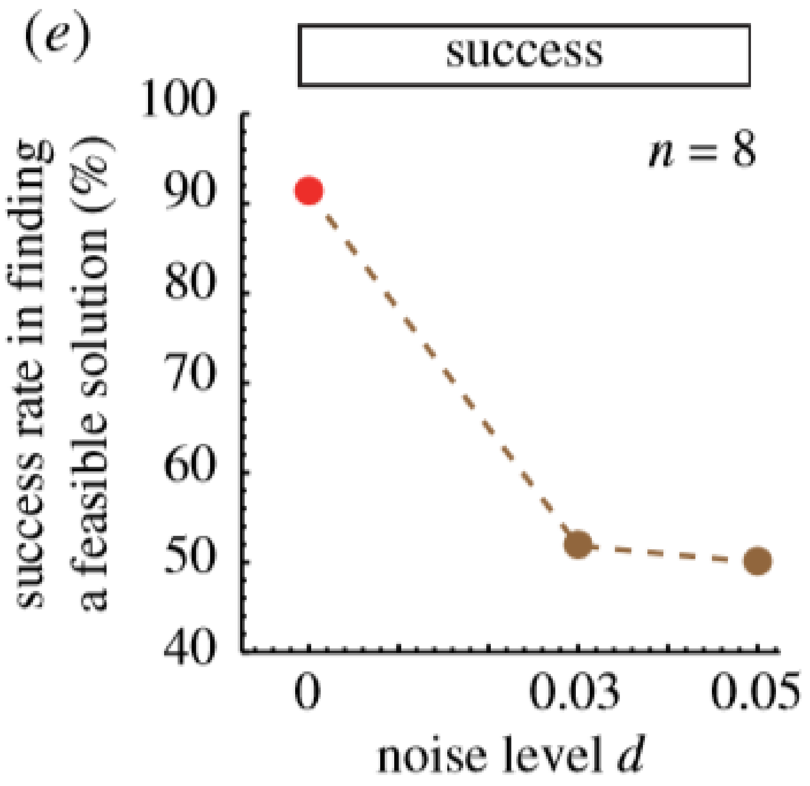
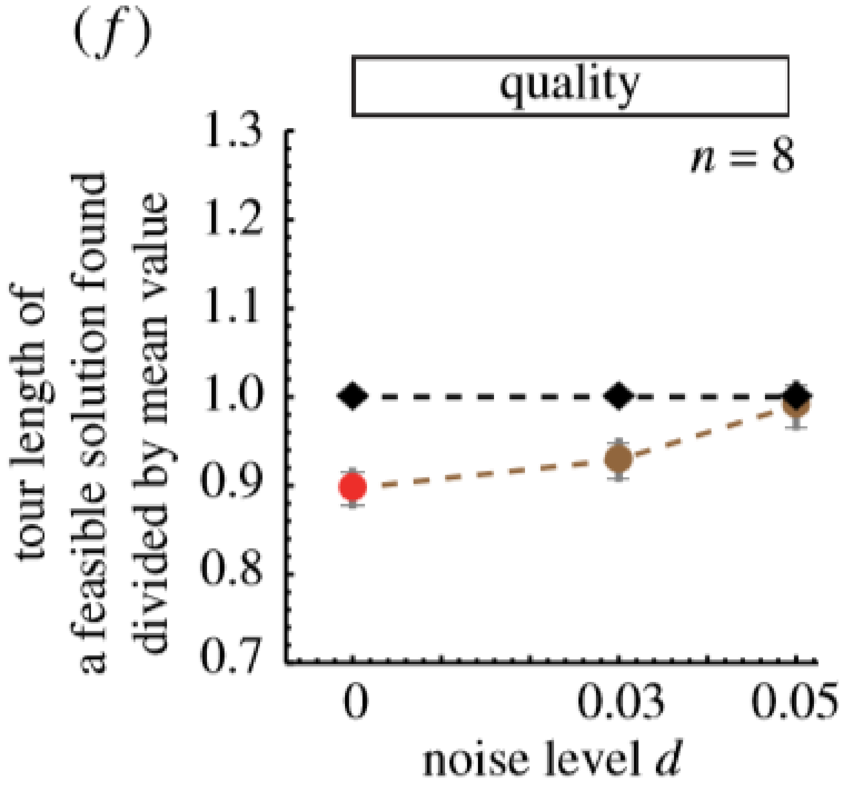
no. cities n
(c)
time
time to find a feasible solution (min)
60
50
40
30
20
10
4
5
6
7
8
no. cities n
(d)
quality
tour length of a feasible solution found divided by mean value
1.3
1.2
1.1
1.0
0.9
0.8
0.7
4
5
6
7
8
no. cities n

Resultate


(e)
success
n = 8
success rate in finding
a feasible solution (%)
100
90
80
70
60
50
40
0
0.03
0.05
noise level d


(f)
quality
n = 8
tour length of
a feasible solution found
divided by mean value
1.3
1.2
1.1
1.0
0.9
0.8
0.7
0
0.03
0.05
noise level d

AmoebaTSP - Initialisierung

$t = 0$;
FOR $Vk = City_1 1$ to $City_n n$, $Ul = City_1 1$ to $City_n n$
  Determine coupling weight $W_{Vk,Ul}$ according to Eq. (3) ;
FOR $Vk = City_1 1$ to $City_n n$
  Initialize $X_{Vk}(0) = X_0$ such that $\sigma_{35,0.6}(X_0) = 1/(n^2 - 1)$;
Initialize $S(0) = 0$;

AmoebaTSP - Oszillation

WHILE $t < t_{Max}$ do
  IF a configuration of all $X_{Vk}(t)$ represents a consistent TSP *tour*
  THEN RETURN the *tour* ;
  ELSE
    FOR $Vk = City_1 1$ to $City_n n$
      Determine $\epsilon_{Vk}(t)$ as a randomly chosen real number in $(-0.003, 0.003)$;
      Determine $L_{Vk}(t+1) = 1 - \sigma_{1000,-0.5}(\sum_{Ul} W_{Vk,Ul} \cdot \sigma_{35,0.6}(X_{Ul}(t) + \epsilon_{Vk}(t)))$;
      IF lane Vk is illuminated $(L_{Vk}(t+1) > 0.5)$
      THEN Determine $O_{Vk}(t+1) = 2 \cdot \Delta^{out} \cdot \sigma_{20,0.6}(X_{Vk}(t) + \epsilon_{Vk}(t))$;
      ELSE Determine $O_{Vk}(t+1) = 0$;
    CALL StockRedistribution ;
    FOR $Vk = City_1 1$ to $City_n n$
      IF lane Vk is not illuminated $(L_{Vk}(t+1) \leq 0.5)$
      THEN Update $X_{Vk}(t+1) = X_{Vk}(t) + I_{Vk}(t+1)$;
      ELSE Update $X_{Vk}(t+1) = X_{Vk}(t) - O_{Vk}(t+1)$;
END WHILE

AmoebaTSP – Ressourcen-Verteilung

SUBROUTINE: StockRedistribution

Determine $L^{off}(t+1)$ as the number of non-illuminated $(L_{Vk}(t+1) \leq 0.5)$ lanes ;

IF $L^{off}(t+1) = 0$

THEN Update $S(t+1) = S(t) + \sum_{Vk} O_{Vk}(t+1) + \Delta^{in}$;

Determine $I_{Vk}(t+1) = 0$;

ELSE Update $S(t+1) = 0$;

Determine $I_{Vk}(t+1) = (S(t) + \sum_{Vk} O_{Vk}(t+1) + \Delta^{in})/L^{off}(t+1)$;

END SUBROUTINE

AmoebaTSP - Probleme

AmoebaTSP - Probleme

$$L_{Vk}(t + \Delta t) = 1 - \sigma_{1000,-0.5}\left(\sum\nolimits_{Ul} W_{Vk,Ul} * \sigma_{35,0.6}\big(X_{Ul}(t)\big)\right)$$

$$W_{Vk,Ul} \begin{cases} -0.5 & \text{Wenn } V = U \text{ und } k \neq l \\ -0.5 & \text{Wenn } V \neq U \text{ und } k = l \\ -v * dist(V, U) & \text{Wenn } V \neq U \text{ und } |k - l| = 1 \\ 0 & \text{Ansonsten} \end{cases}$$

AmoebaTSP - Probleme

WHILE $t < t_{Max}$ do
  IF a configuration of all $X_{Vk}(t)$ represents a consistent TSP *tour*
  THEN RETURN the *tour* ;
  ELSE
    FOR $Vk = City_1 1$ to $City_n n$
      Determine $\epsilon_{Vk}(t)$ as a randomly chosen real number in $(-0.003, 0.003)$;
      Determine $L_{Vk}(t+1) = 1 - \sigma_{1000,-0.5}(\sum_{Ul} W_{Vk,Ul} \cdot \sigma_{35,0.6}(X_{Ul}(t) + \epsilon_{Vk}(t)))$;
      IF lane Vk is illuminated $(L_{Vk}(t+1) > 0.5)$
      THEN Determine $O_{Vk}(t+1) = 2 \cdot \Delta^{out} \cdot \sigma_{20,0.6}(X_{Vk}(t) + \epsilon_{Vk}(t))$;
      ELSE Determine $O_{Vk}(t+1) = 0$;
    CALL StockRedistribution ;
    FOR $Vk = City_1 1$ to $City_n n$
      IF lane Vk is not illuminated $(L_{Vk}(t+1) \leq 0.5)$
      THEN Update $X_{Vk}(t+1) = X_{Vk}(t) + I_{Vk}(t+1)$;
      ELSE Update $X_{Vk}(t+1) = X_{Vk}(t) - O_{Vk}(t+1)$;
END WHILE

AmoebaTSP - Probleme

WHILE $t < t_{Max}$ do

IF a configuration of all $X_{Vk}(t)$ represents a consistent TSP *tour*

THEN RETURN the *tour* ;

ELSE

$\boxed{\text{FOR } Vk = City_1 1 \text{ to } City_n n}$

Determine $\epsilon_{Vk}(t)$ as a randomly chosen real number in $(-0.003, 0.003)$;

Determine $L_{Vk}(t+1) = 1 - \sigma_{1000,-0.5}(\boxed{\sum_{Ul}} W_{Vk,Ul} \cdot \sigma_{35,0.6}(X_{Ul}(t) + \epsilon_{Vk}(t)))$;

IF lane Vk is illuminated $(L_{Vk}(t+1) > 0.5)$

THEN Determine $O_{Vk}(t+1) = 2 \cdot \Delta^{out} \cdot \sigma_{20,0.6}(X_{Vk}(t) + \epsilon_{Vk}(t))$;

ELSE Determine $O_{Vk}(t+1) = 0$;

CALL StockRedistribution ;

FOR $Vk = City_1 1$ to $City_n n$

IF lane Vk is not illuminated $(L_{Vk}(t+1) \leq 0.5)$

THEN Update $X_{Vk}(t+1) = X_{Vk}(t) + I_{Vk}(t+1)$;

ELSE Update $X_{Vk}(t+1) = X_{Vk}(t) - O_{Vk}(t+1)$;

END WHILE

AmoebaTSP - Probleme

WHILE $t < t_{Max}$ do

  IF a configuration of all $X_{Vk}(t)$ represents a consistent TSP *tour*

  THEN RETURN the *tour* ;

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      IF lane Vk is illuminated $(L_{Vk}(t+1) > 0.5)$

      THEN Determine $O_{Vk}(t+1) = 2 \cdot \Delta^{out} \cdot \sigma_{20,0.6}(X_{Vk}(t) + \epsilon_{Vk}(t))$;

      ELSE Determine $O_{Vk}(t+1) = 0$;

    CALL StockRedistribution ;

    FOR $Vk = City_1 1$ to $City_n n$

      IF lane Vk is not illuminated $(L_{Vk}(t+1) \leq 0.5)$

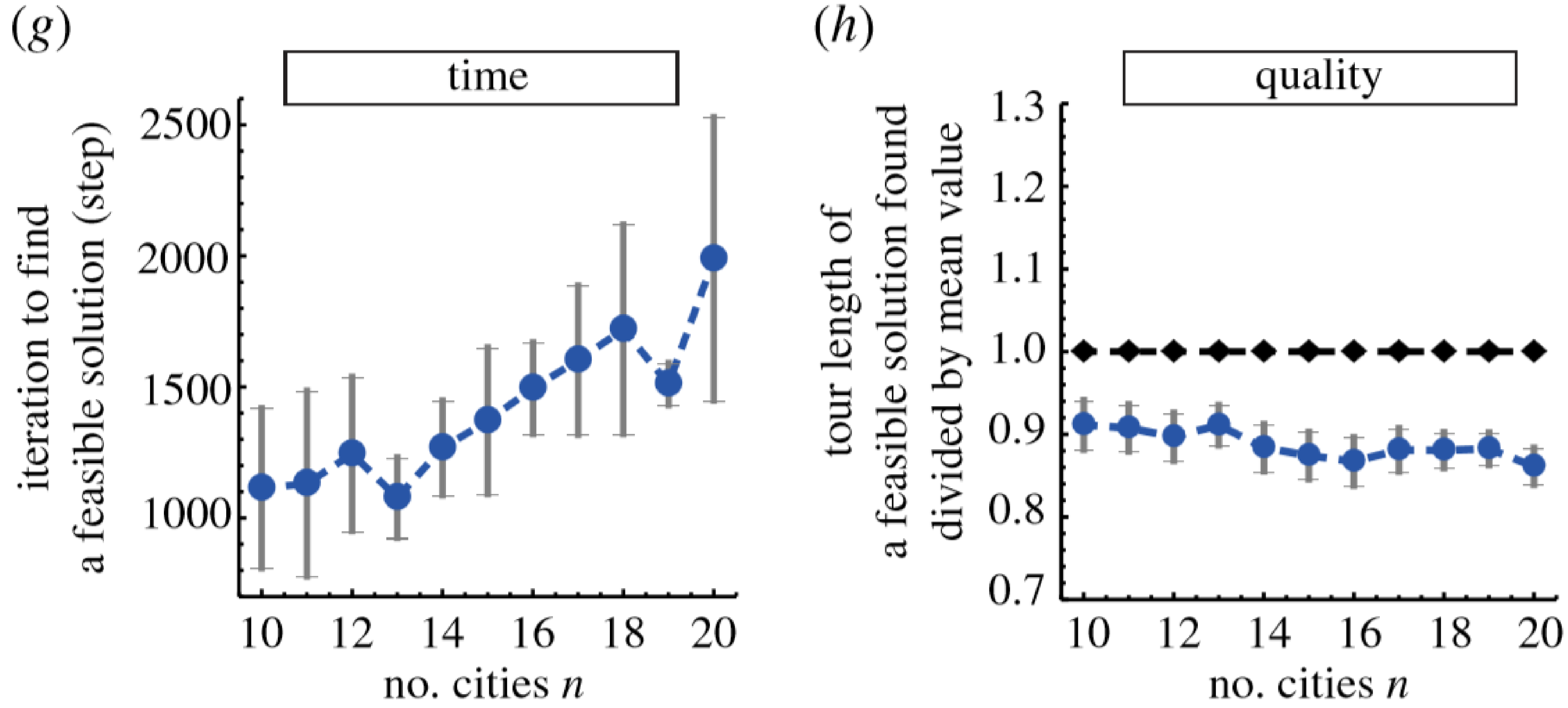
      THEN Update $X_{Vk}(t+1) = X_{Vk}(t) + I_{Vk}(t+1)$;

      ELSE Update $X_{Vk}(t+1) = X_{Vk}(t) - O_{Vk}(t+1)$;

END WHILE

$O(n^4)$

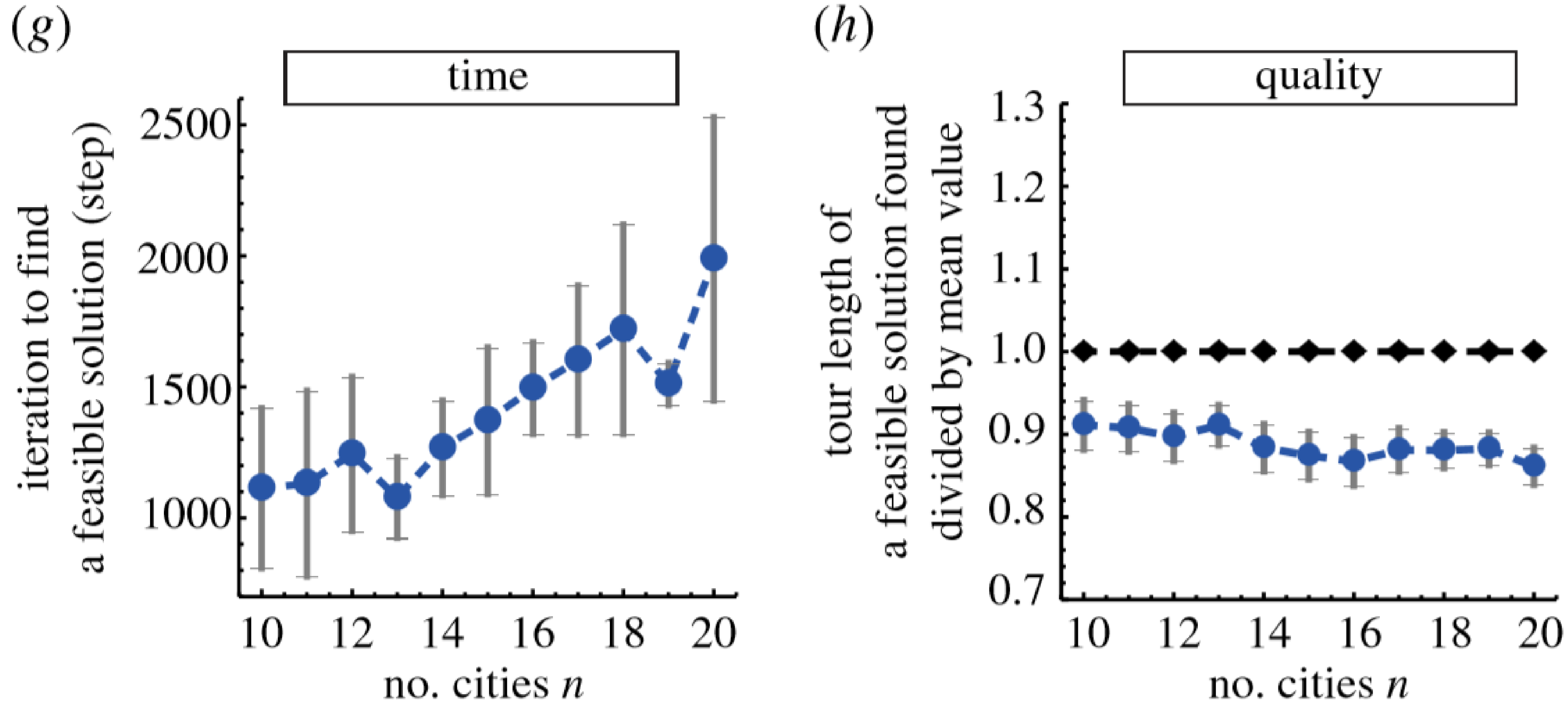
AmoebaTSP – Parallel Computing



AmoebaTSP – Dennoch Probleme?

WHILE $t < t_{Max}$ do
  IF a configuration of all $X_{Vk}(t)$ represents a consistent TSP *tour*
  THEN RETURN the *tour* ;
  ELSE
    FOR $Vk = City_1 1$ to $City_n n$
      Determine $\epsilon_{Vk}(t)$ as a randomly chosen real number in $(-0.003, 0.003)$;
      Determine $L_{Vk}(t+1) = 1 - \sigma_{1000,-0.5}(\boxed{\sum_{Ul}} W_{Vk,Ul} \cdot \sigma_{35,0.6}(X_{Ul}(t) + \epsilon_{Vk}(t)))$;
      IF lane Vk is illuminated $(L_{Vk}(t+1) > 0.5)$
      THEN Determine $O_{Vk}(t+1) = 2 \cdot \Delta^{out} \cdot \sigma_{20,0.6}(X_{Vk}(t) + \epsilon_{Vk}(t))$;
      ELSE Determine $O_{Vk}(t+1) = 0$;
    CALL StockRedistribution ;
    FOR $Vk = City_1 1$ to $City_n n$
      IF lane Vk is not illuminated $(L_{Vk}(t+1) \leq 0.5)$
      THEN Update $X_{Vk}(t+1) = X_{Vk}(t) + I_{Vk}(t+1)$;
      ELSE Update $X_{Vk}(t+1) = X_{Vk}(t) - O_{Vk}(t+1)$;
END WHILE

AmoebaTSP – Dennoch Probleme?



Quellen

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- https://www.wolframalpha.com/input/?i=plot+1%2F(1%2Bexp(-1000*(x%2B0.5)))(x+from+-1.5+to+0.5)
- https://www.wolframalpha.com/input/?i=plot+(1-(1%2F(1%2Bexp(-1000*(x%2B0.5)))))(x+from+-1.5+to+0.5)
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Bild-Quellen

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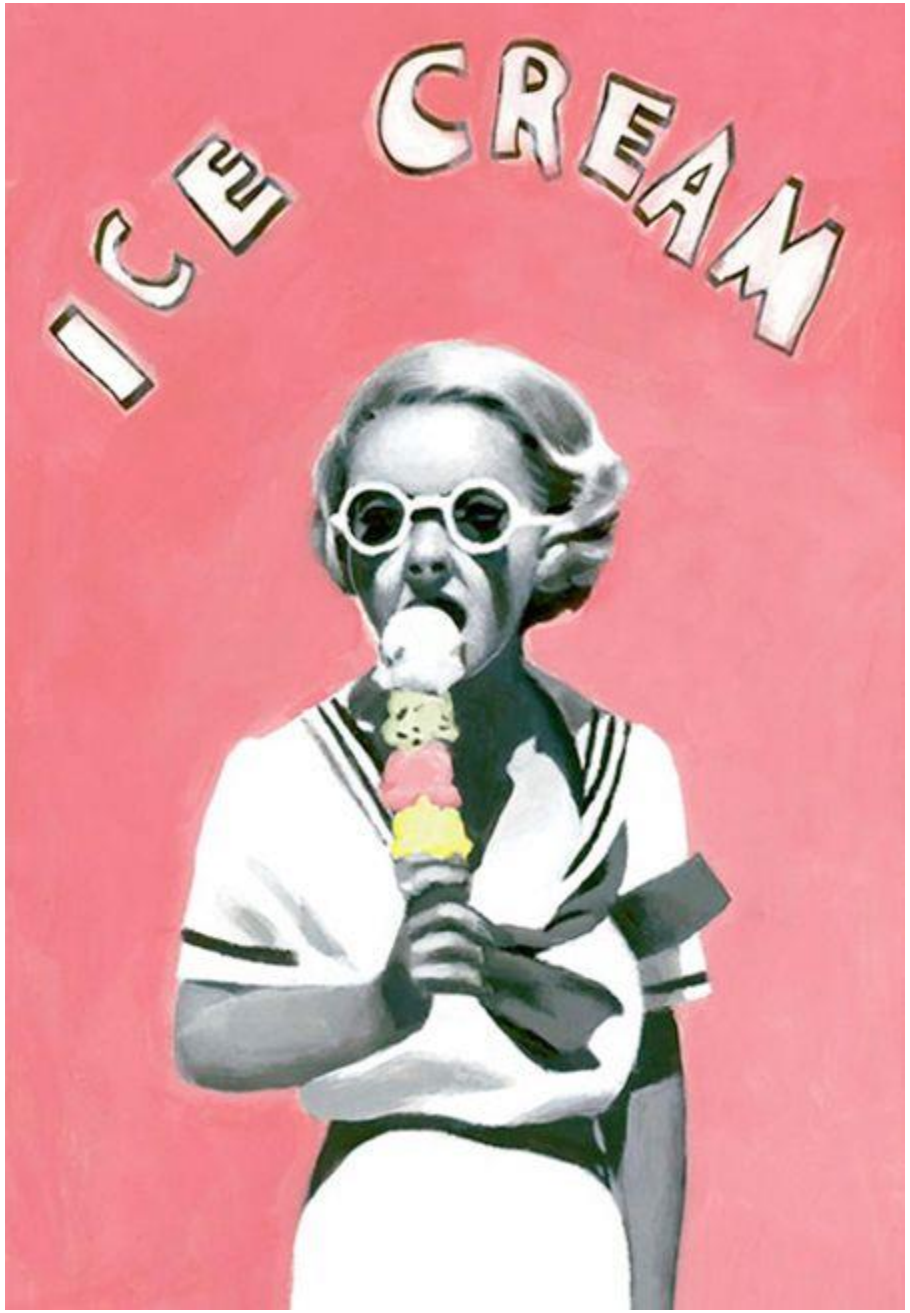

Vielen Dank für eure Aufmerksamkeit!

Noch Fragen?!