

Data Mining
Tutorial

E. Schubert,
A. Zimek

Outlier
detection

Aufgabe 9-2

Data Mining Tutorial

Outlier Detection

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Ludwig-Maximilians-Universität München

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Distanzbasierte Ausreißer

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Distanzbasierte Ausreißer:
“Ausreißer sind weiter weg von den anderen Daten”

- ▶ Distanz zum nächsten Nachbarn



Distanzbasierte Ausreißer

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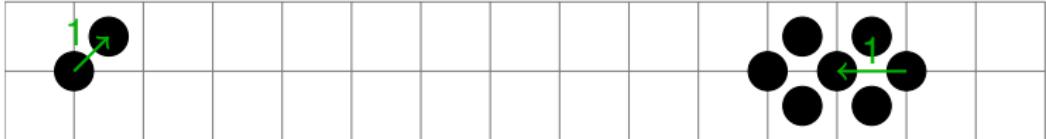
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Distanzbasierte Ausreißer:
“Ausreißer sind weiter weg von den anderen Daten”

- ▶ Distanz zum nächsten Nachbarn
⇒ übersieht Ausreißer-Paare



Distanzbasierte Ausreißer

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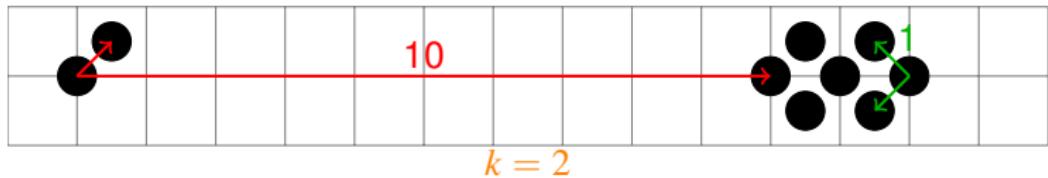
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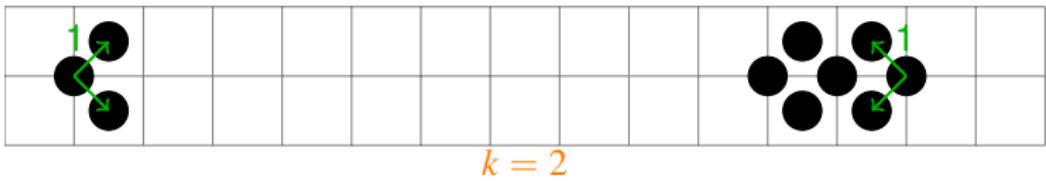
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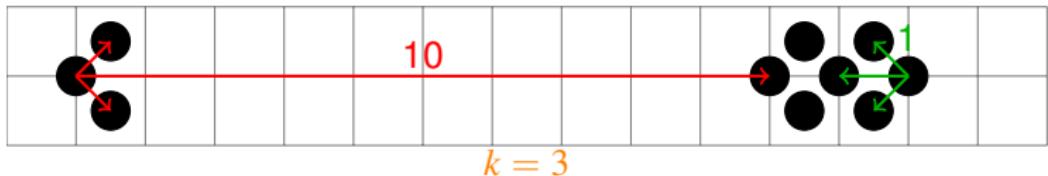
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Distanzbasierte Ausreißer:
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- ▶ Distanz zum k nächsten Nachbarn
 \Rightarrow Micro-Cluster ($|C| < k + 1$) werden Ausreißer



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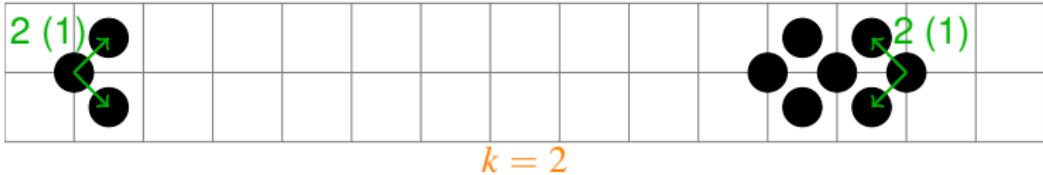
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Distanzbasierte Ausreißer:
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- ▶ Summe der Distanzen zu den k nächsten Nachbarn
Etwas robuster bzgl. k und Micro-Clustern



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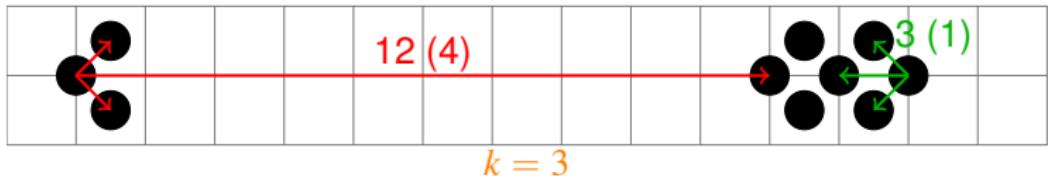
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Distanzbasierte Ausreißer

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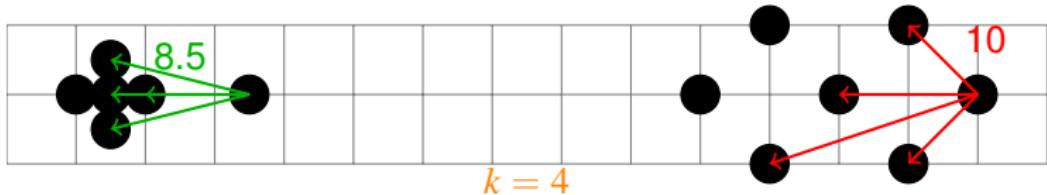
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Distanzbasierte Ausreißer:
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- ▶ Summe der Distanzen zu den k nächsten Nachbarn
⇒ Kann aber nicht gut mit unterschiedlichen Dichten umgehen!



Local Outlier Factor

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Idee: Ein Ausreißer ist weniger dicht als seine Nachbarn

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Idee: Ein Ausreißer ist weniger dicht als seine Nachbarn
Dichteschätzung basierend auf den Ideen der
Clusteringalgorithmen OPTICS und DBSCAN:
“Wann wäre ein Objekt p im minPts -Kern von o ?“

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$$\text{reach-dist}_k(p, o) = \max\{\text{k-distance}(o), \text{dist}(o, p)\}$$

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$$\text{reach-dist}_k(p, o) = \max \underbrace{\{k\text{-distance}(o), \text{dist}(o, p)\}}_{k\text{NN outlier!}}$$

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$$\text{reach-dist}_k(p \leftarrow o) = \max\{\text{k-distance}(o), \text{dist}(o, p)\}$$

Vorsicht: diese “Distanz” ist nicht symmetrisch!
Sie hängt von der Kerngröße des anderen Objekts o ab.
Ich bevorzuge die Notation “ p erreichbar von o “:

$$\text{reach-dist}_k(p \leftarrow o)$$

um das zu betonen.

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$$\text{reach-dist}_k(p \leftarrow o) = \max\{\text{k-distance}(o), \text{dist}(o, p)\}$$

Lokale Erreichbarkeitsdichte

$$\text{lrd}_k(p) = 1 / \left(\frac{\sum_{o \in \mathcal{N}} \text{reach-dist}_k(p \leftarrow o)}{|\mathcal{N}|} \right)$$

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Lokale Erreichbarkeitsdichte

$$\text{lrd}_k(p) = 1 / \left(\frac{1}{|\mathcal{N}|} \sum_{o \in \mathcal{N}} \text{reach-dist}_k(p \leftarrow o) \right)$$

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$$\text{reach-dist}_k(p \leftarrow o) = \max\{\text{k-distance}(o), \text{dist}(o, p)\}$$

Lokale Erreichbarkeitsdichte

$$\text{lrd}_k(p) = \underbrace{1}_{\text{Kehrwert}} \Bigg/ \underbrace{\left(\frac{1}{|\mathcal{N}|} \sum_{o \in \mathcal{N}} \underbrace{\text{reach-dist}_k(p \leftarrow o)}_{\text{Erreichbarkeit von den Nachbarn}} \right)}$$

Vorsicht: Division durch 0 (aber nicht bei Ausreißern!)

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Outlier
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$$LOF(p) = \frac{\sum_{o \in \mathcal{N}} \text{Ird}_k(o)}{|\mathcal{N}|}$$

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Data Mining
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A. Zimek

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Aufgabe 9-2

$$LOF(p) = \frac{1}{|\mathcal{N}|} \sum_{o \in \mathcal{N}} \frac{lrd_k(o)}{lrd_k(p)}$$

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A. Zimek

Outlier
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Aufgabe 9-2

$$LOF(p) = \underbrace{\frac{1}{|\mathcal{N}|} \sum_{o \in \mathcal{N}}}_{\text{Mittlere}} \underbrace{\frac{lrd_k(o)}{lrd_k(p)}}_{\text{relative Dichte (der Nachbarn!)}}$$

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Data Mining
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Outlier
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Aufgabe 9-2

$$LOF(p) = \underbrace{\frac{1}{|\mathcal{N}|} \sum_{o \in \mathcal{N}}}_{\text{Mittlere}} \underbrace{\frac{lrd_k(o)}{lrd_k(p)}}_{\text{relative Dichte (der Nachbarn!)}}$$

- p gleich dicht \Leftrightarrow relative Dichte = 1

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Outlier
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$$LOF(p) = \underbrace{\frac{1}{|\mathcal{N}|} \sum_{o \in \mathcal{N}}}_{\text{Mittlere}} \underbrace{\frac{lrd_k(o)}{lrd_k(p)}}_{\text{relative Dichte (der Nachbarn!)}}$$

- ▶ p gleich dicht \Leftrightarrow relative Dichte = 1
- ▶ p ähnlich dicht \Leftrightarrow relative Dichte ≈ 1

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Outlier
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- ▶ p gleich dicht \Leftrightarrow relative Dichte = 1
- ▶ p ähnlich dicht \Leftrightarrow relative Dichte ≈ 1
- ▶ p weniger dicht \Leftrightarrow relative Dichte > 1

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$$LOF(p) = \underbrace{\frac{1}{|\mathcal{N}|} \sum_{o \in \mathcal{N}}}_{\text{Mittlere}} \underbrace{\frac{lrd_k(o)}{lrd_k(p)}}_{\text{relative Dichte (der Nachbarn!)}}$$

- ▶ p gleich dicht \Leftrightarrow relative Dichte = 1
- ▶ p ähnlich dicht \Leftrightarrow relative Dichte ≈ 1
- ▶ p weniger dicht \Leftrightarrow relative Dichte > 1
- ▶ $LOF(p) \gg 1$ für Ausreißer!

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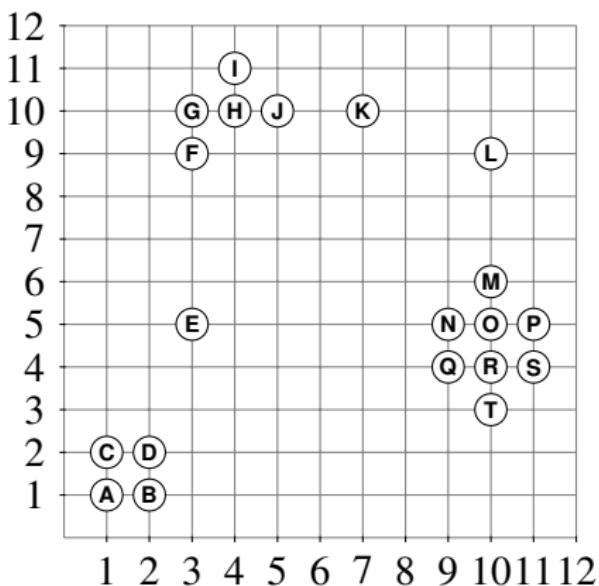
$$LOF(p) = \underbrace{\frac{1}{|\mathcal{N}|} \sum_{o \in \mathcal{N}}}_{\text{Mittlere}} \underbrace{\frac{lrd_k(o)}{lrd_k(p)}}_{\text{relative Dichte (der Nachbarn!)}}$$

- ▶ p gleich dicht \Leftrightarrow relative Dichte = 1
- ▶ p ähnlich dicht \Leftrightarrow relative Dichte ≈ 1
- ▶ p weniger dicht \Leftrightarrow relative Dichte > 1
- ▶ $LOF(p) \gg 1$ für Ausreißer!

Hinweis: Dichte im Sinne von OPTICS/DBSCAN!
Die Erreichbarkeitsdistanz (lrd) wird oft übersehen!

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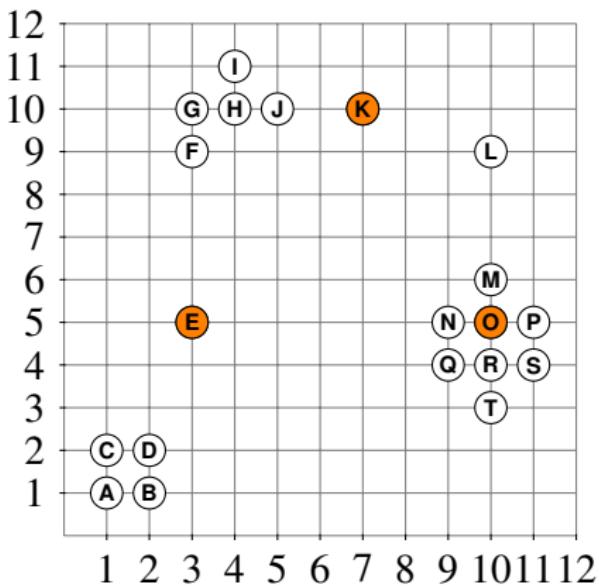
Aufgabe 9-2



| | 2NN | 2d. | 4NN | 4d. |
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| A | | | | |
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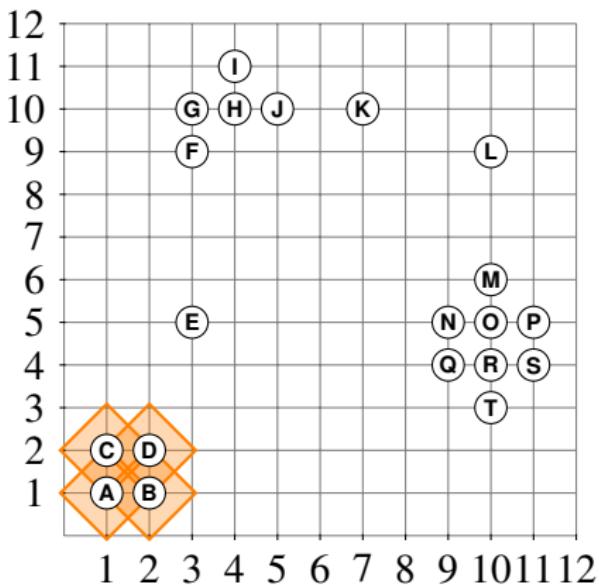
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|---|-----|-----|-----|-----|
| A | | | | |
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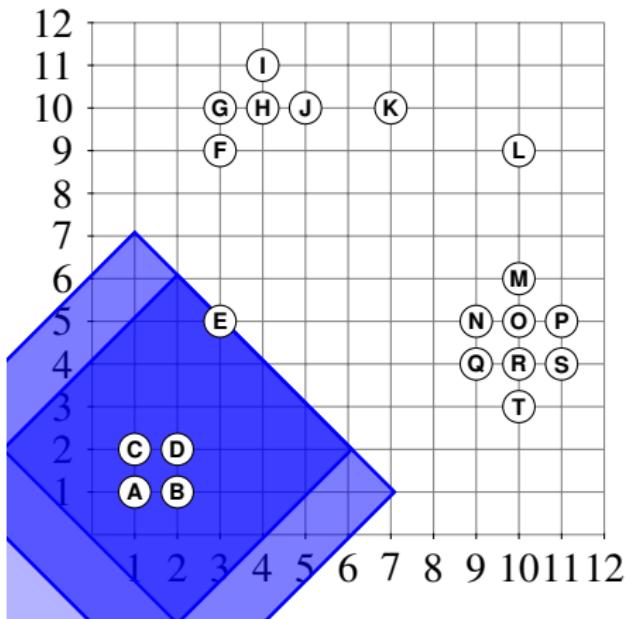
Aufgabe 9-2



| | 2NN | 2d. | 4NN | 4d. |
|---|-----|-----|-----|-----|
| A | B C | 1 | | |
| B | A D | 1 | | |
| C | A D | 1 | | |
| D | B C | 1 | | |
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| H | I | | | |
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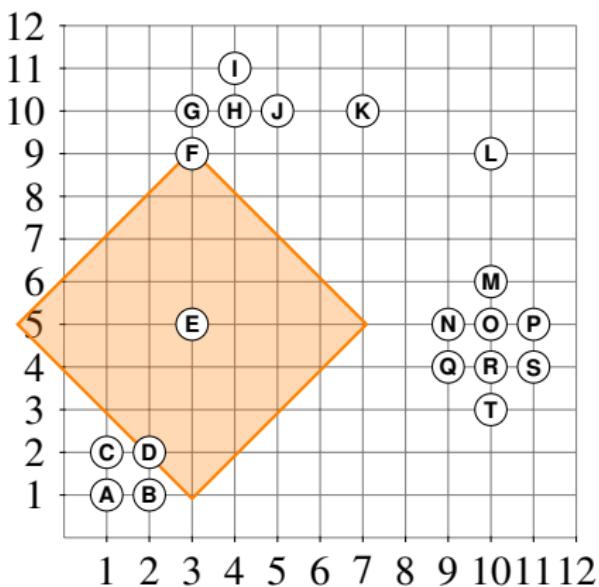
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| | 2NN | 2d. | 4NN | 4d. |
|---|-----|-----|---------|-----|
| A | B C | 1 | B C D E | 6 |
| B | A D | 1 | A C D E | 5 |
| C | A D | 1 | A B D E | 5 |
| D | B C | 1 | A B C E | 4 |
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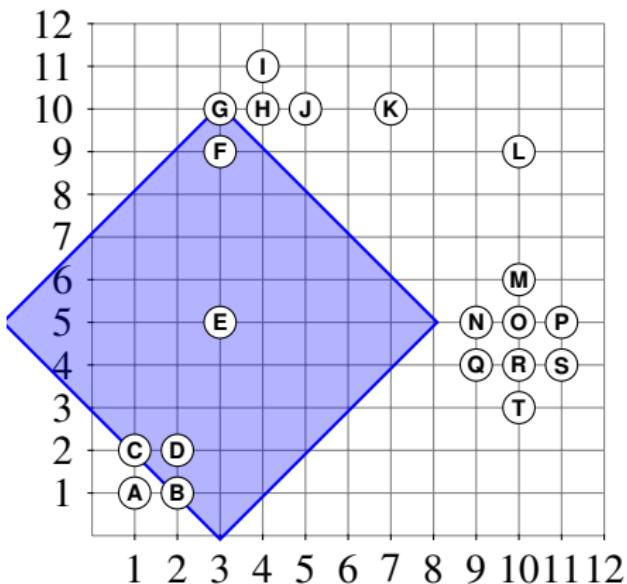
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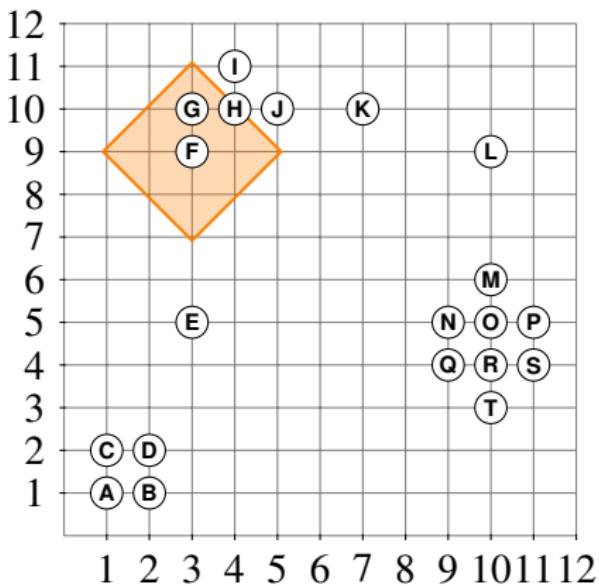
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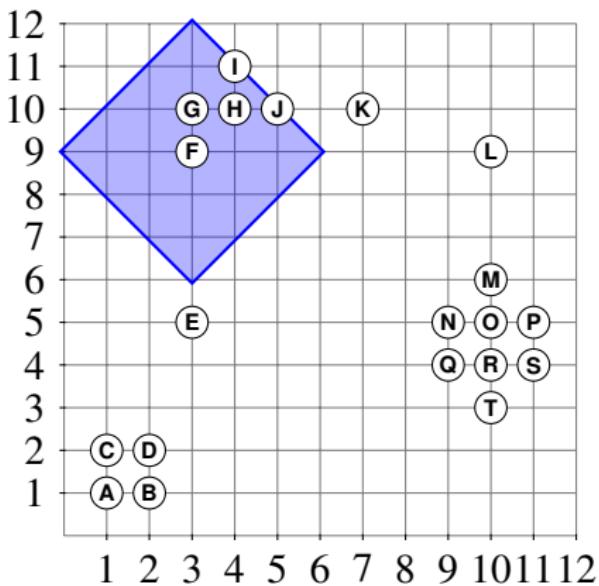
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| D | B C | 1 | A B C E | 4 |
| E | D F | 4 | B C D F G | 5 |
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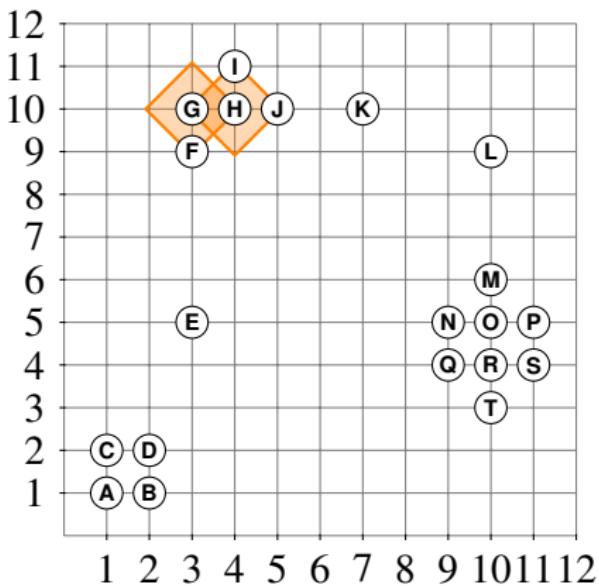
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| D | B C | 1 | A B C E | 4 |
| E | D F | 4 | B C D F G | 5 |
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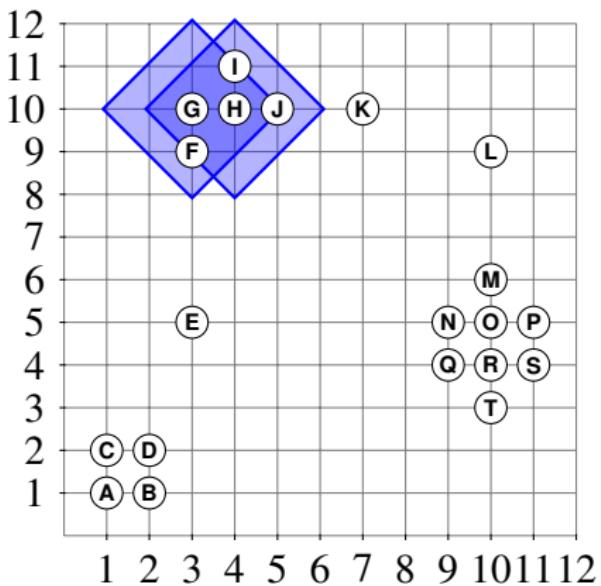
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| C | A D | 1 | A B D E | 5 |
| D | B C | 1 | A B C E | 4 |
| E | D F | 4 | B C D F G | 5 |
| F | G H | 2 | G H I J | 3 |
| G | F H | 1 | | |
| H | G I J | 1 | | |
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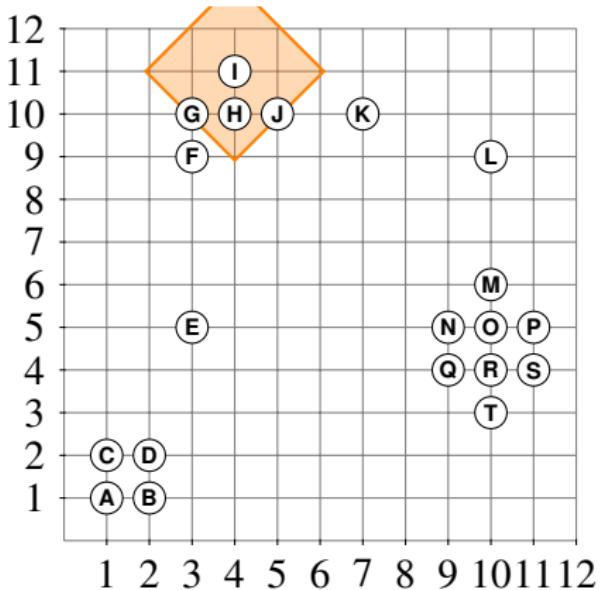
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| D | B C | 1 | A B C E | 4 |
| E | D F | 4 | B C D F G | 5 |
| F | G H | 2 | G H I J | 3 |
| G | F H | 1 | F H I J | 2 |
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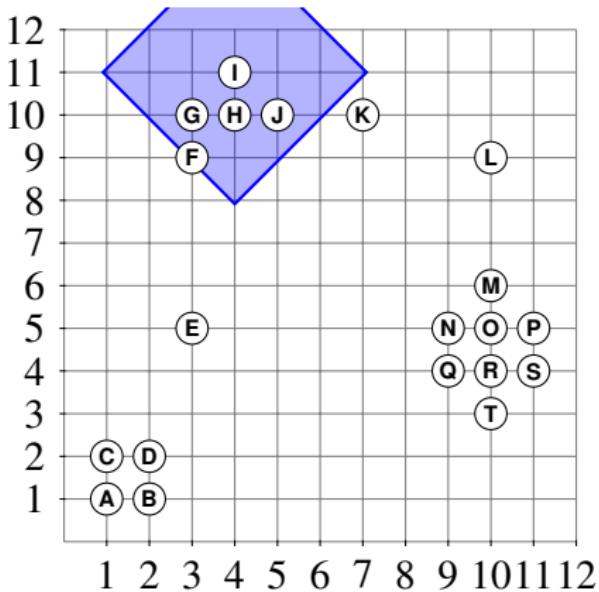
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| | 2NN | 2d. | 4NN | 4d. |
|---|-------|-----|-----------|-----|
| A | B C | 1 | B C D E | 6 |
| B | A D | 1 | A C D E | 5 |
| C | A D | 1 | A B D E | 5 |
| D | B C | 1 | A B C E | 4 |
| E | D F | 4 | B C D F G | 5 |
| F | G H | 2 | G H I J | 3 |
| G | F H | 1 | F H I J | 2 |
| H | G I J | 1 | F G I J | 2 |
| I | G H J | 2 | | |
| J | | | | |
| K | | | | |
| L | | | | |
| M | | | | |
| N | | | | |
| O | | | | |
| P | | | | |
| Q | | | | |
| R | | | | |
| S | | | | |
| T | | | | |

LOF und k NNData Mining
TutorialE. Schubert,
A. ZimekOutlier
detection

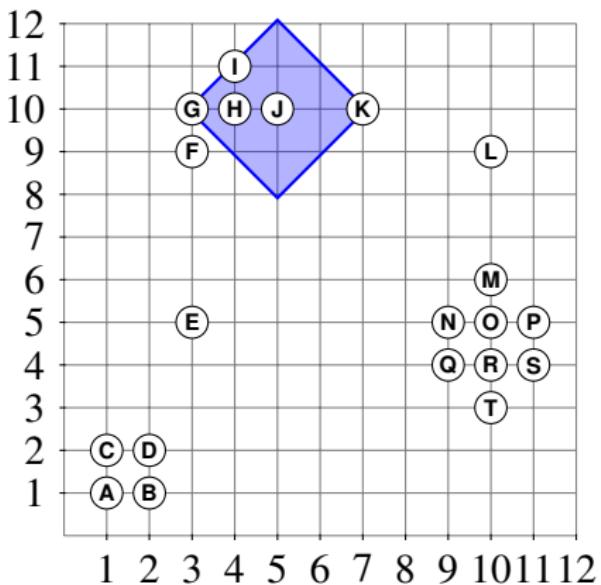
Aufgabe 9-2



| | 2NN | 2d. | 4NN | 4d. |
|---|-------|-----|-----------|-----|
| A | B C | 1 | B C D E | 6 |
| B | A D | 1 | A C D E | 5 |
| C | A D | 1 | A B D E | 5 |
| D | B C | 1 | A B C E | 4 |
| E | D F | 4 | B C D F G | 5 |
| F | G H | 2 | G H I J | 3 |
| G | F H | 1 | F H I J | 2 |
| H | G I J | 1 | F G I J | 2 |
| I | G H J | 2 | F G H J | 3 |
| J | | | | |
| K | | | | |
| L | | | | |
| M | | | | |
| N | | | | |
| O | | | | |
| P | | | | |
| Q | | | | |
| R | | | | |
| S | | | | |
| T | | | | |

LOF und k NNData Mining
TutorialE. Schubert,
A. ZimekOutlier
detection

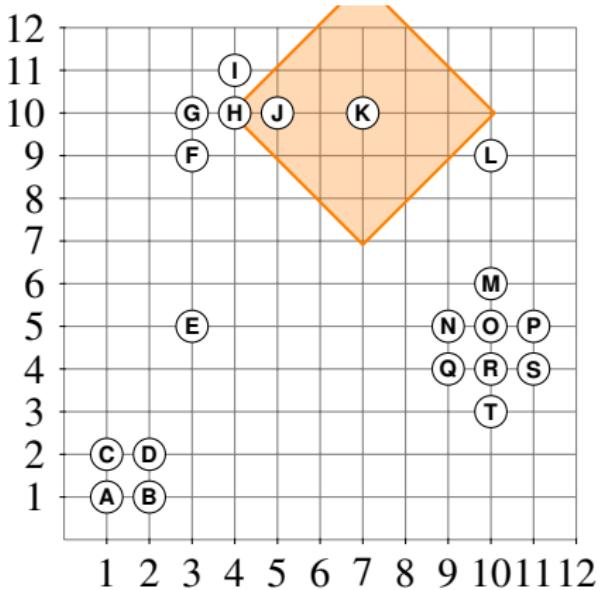
Aufgabe 9-2



| | 2NN | 2d. | 4NN | 4d. |
|---|---------|-----|-----------|-----|
| A | B C | 1 | B C D E | 6 |
| B | A D | 1 | A C D E | 5 |
| C | A D | 1 | A B D E | 5 |
| D | B C | 1 | A B C E | 4 |
| E | D F | 4 | B C D F G | 5 |
| F | G H | 2 | G H I J | 3 |
| G | F H | 1 | F H I J | 2 |
| H | G I J | 1 | F G I J | 2 |
| I | G H J | 2 | F G H J | 3 |
| J | G H I K | 2 | G H I K | 2 |
| K | | | | |
| L | | | | |
| M | | | | |
| N | | | | |
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| P | | | | |
| Q | | | | |
| R | | | | |
| S | | | | |
| T | | | | |

LOF und k NNData Mining
TutorialE. Schubert,
A. ZimekOutlier
detection

Aufgabe 9-2

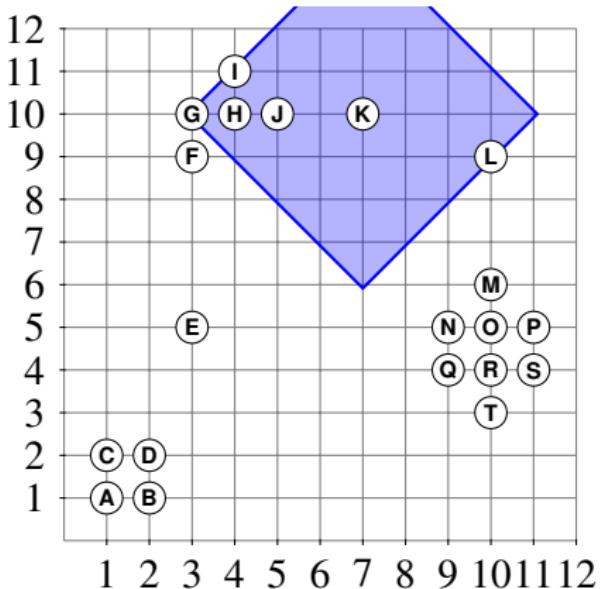


| | 2NN | 2d. | 4NN | 4d. |
|---|---------|-----|-----------|-----|
| A | B C | 1 | B C D E | 6 |
| B | A D | 1 | A C D E | 5 |
| C | A D | 1 | A B D E | 5 |
| D | B C | 1 | A B C E | 4 |
| E | D F | 4 | B C D F G | 5 |
| F | G H | 2 | G H I J | 3 |
| G | F H | 1 | F H I J | 2 |
| H | G I J | 1 | F G I J | 2 |
| I | G H J | 2 | F G H J | 3 |
| J | G H I K | 2 | G H I K | 2 |
| K | H J | 3 | | |
| L | | | | |
| M | | | | |
| N | | | | |
| O | | | | |
| P | | | | |
| Q | | | | |
| R | | | | |
| S | | | | |
| T | | | | |

LOF und kNN

Data Mining
TutorialE. Schubert,
A. ZimekOutlier
detection

Aufgabe 9-2

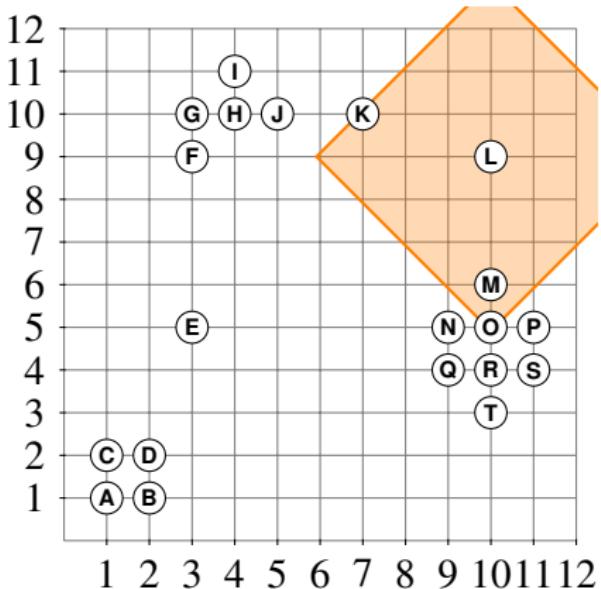


| | 2NN | 2d. | 4NN | 4d. |
|---|---------|-----|-----------|-----|
| A | B C | 1 | B C D E | 6 |
| B | A D | 1 | A C D E | 5 |
| C | A D | 1 | A B D E | 5 |
| D | B C | 1 | A B C E | 4 |
| E | D F | 4 | B C D F G | 5 |
| F | G H | 2 | G H I J | 3 |
| G | F H | 1 | F H I J | 2 |
| H | G I J | 1 | F G I J | 2 |
| I | G H J | 2 | F G H J | 3 |
| J | G H I K | 2 | G H I K | 2 |
| K | H J | 3 | G H I J L | 4 |
| L | | | | |
| M | | | | |
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| S | | | | |
| T | | | | |

LOF und kNN

Data Mining
TutorialE. Schubert,
A. ZimekOutlier
detection

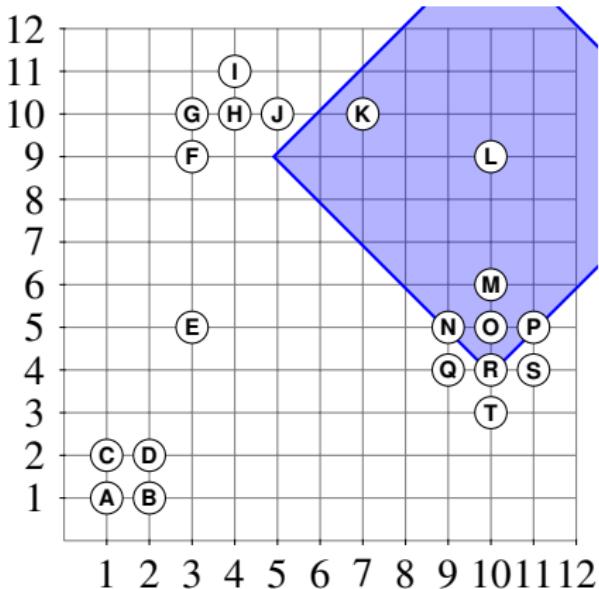
Aufgabe 9-2



| | 2NN | 2d. | 4NN | 4d. |
|---|---------|-----|-----------|-----|
| A | B C | 1 | B C D E | 6 |
| B | A D | 1 | A C D E | 5 |
| C | A D | 1 | A B D E | 5 |
| D | B C | 1 | A B C E | 4 |
| E | D F | 4 | B C D F G | 5 |
| F | G H | 2 | G H I J | 3 |
| G | F H | 1 | F H I J | 2 |
| H | G I J | 1 | F G I J | 2 |
| I | G H J | 2 | F G H J | 3 |
| J | G H I K | 2 | G H I K | 2 |
| K | H J | 3 | G H I J L | 4 |
| L | K M O | 4 | | |
| M | | | | |
| N | | | | |
| O | | | | |
| P | | | | |
| Q | | | | |
| R | | | | |
| S | | | | |
| T | | | | |

LOF und k NNData Mining
TutorialE. Schubert,
A. ZimekOutlier
detection

Aufgabe 9-2

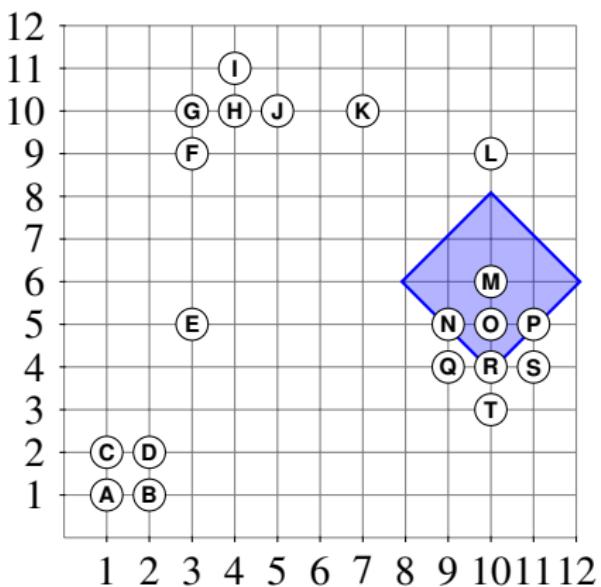


| | 2NN | 2d. | 4NN | 4d. |
|---|---------|-----|-------------|-----|
| A | B C | 1 | B C D E | 6 |
| B | A D | 1 | A C D E | 5 |
| C | A D | 1 | A B D E | 5 |
| D | B C | 1 | A B C E | 4 |
| E | D F | 4 | B C D F G | 5 |
| F | G H | 2 | G H I J | 3 |
| G | F H | 1 | F H I J | 2 |
| H | G I J | 1 | F G I J | 2 |
| I | G H J | 2 | F G H J | 3 |
| J | G H I K | 2 | G H I K | 2 |
| K | H J | 3 | G H I J L | 4 |
| L | K M O | 4 | K M N O P R | 5 |
| M | | | | |
| N | | | | |
| O | | | | |
| P | | | | |
| Q | | | | |
| R | | | | |
| S | | | | |
| T | | | | |

LOF und kNN

Data Mining
TutorialE. Schubert,
A. ZimekOutlier
detection

Aufgabe 9-2

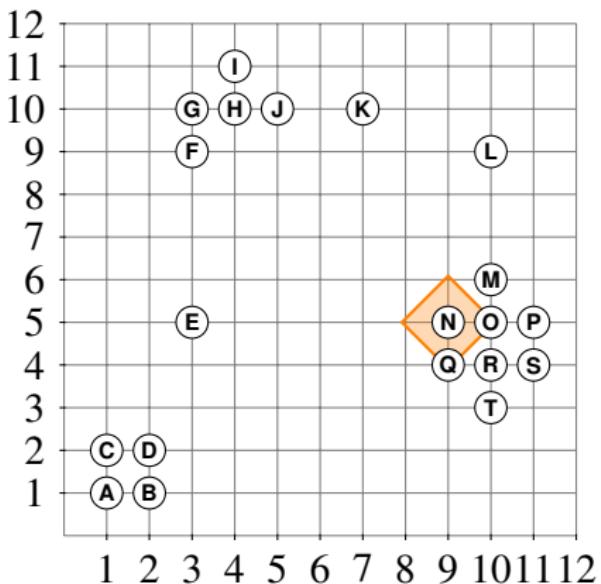


| | 2NN | 2d. | 4NN | 4d. |
|---|---------|-----|-------------|-----|
| A | B C | 1 | B C D E | 6 |
| B | A D | 1 | A C D E | 5 |
| C | A D | 1 | A B D E | 5 |
| D | B C | 1 | A B C E | 4 |
| E | D F | 4 | B C D F G | 5 |
| F | G H | 2 | G H I J | 3 |
| G | F H | 1 | F H I J | 2 |
| H | G I J | 1 | F G I J | 2 |
| I | G H J | 2 | F G H J | 3 |
| J | G H I K | 2 | G H I K | 2 |
| K | H J | 3 | G H I J L | 4 |
| L | K M O | 4 | K M N O P R | 5 |
| M | N O P R | 2 | N O P R | 2 |
| N | | | | |
| O | | | | |
| P | | | | |
| Q | | | | |
| R | | | | |
| S | | | | |
| T | | | | |

LOF und kNN

Data Mining
TutorialE. Schubert,
A. ZimekOutlier
detection

Aufgabe 9-2

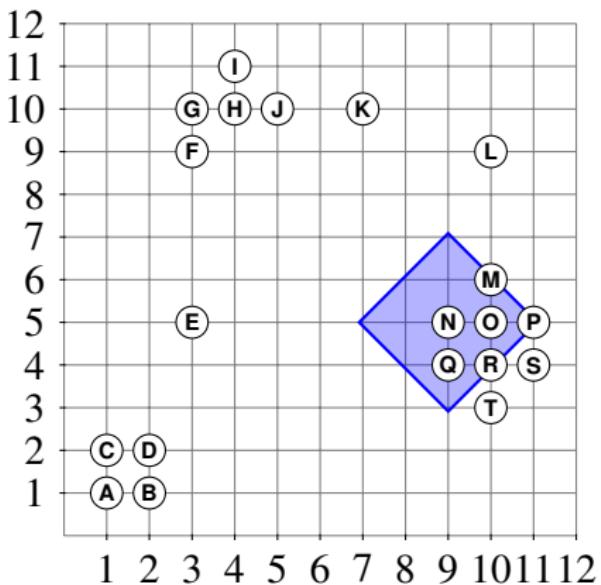


| | 2NN | 2d. | 4NN | 4d. |
|---|---------|-----|-------------|-----|
| A | B C | 1 | B C D E | 6 |
| B | A D | 1 | A C D E | 5 |
| C | A D | 1 | A B D E | 5 |
| D | B C | 1 | A B C E | 4 |
| E | D F | 4 | B C D F G | 5 |
| F | G H | 2 | G H I J | 3 |
| G | F H | 1 | F H I J | 2 |
| H | G I J | 1 | F G I J | 2 |
| I | G H J | 2 | F G H J | 3 |
| J | G H I K | 2 | G H I K | 2 |
| K | H J | 3 | G H I J L | 4 |
| L | K M O | 4 | K M N O P R | 5 |
| M | N O P R | 2 | N O P R | 2 |
| N | O Q | 1 | | |
| O | | | | |
| P | | | | |
| Q | | | | |
| R | | | | |
| S | | | | |
| T | | | | |

LOF und kNN

Data Mining
TutorialE. Schubert,
A. ZimekOutlier
detection

Aufgabe 9-2

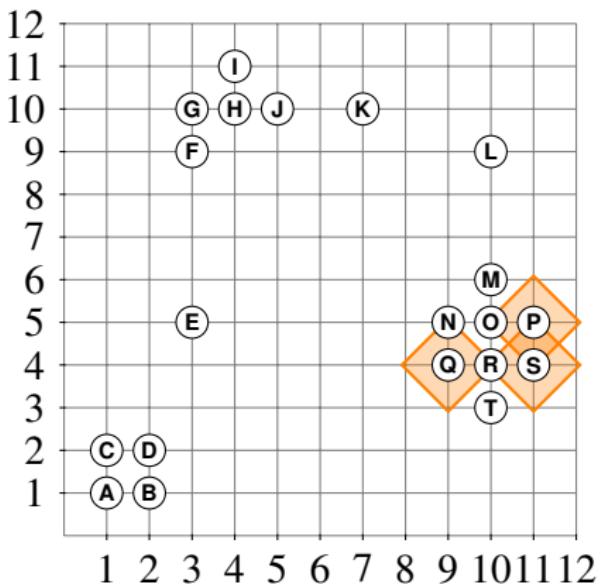


| | 2NN | 2d. | 4NN | 4d. |
|---|---------|-----|-------------|-----|
| A | B C | 1 | B C D E | 6 |
| B | A D | 1 | A C D E | 5 |
| C | A D | 1 | A B D E | 5 |
| D | B C | 1 | A B C E | 4 |
| E | D F | 4 | B C D F G | 5 |
| F | G H | 2 | G H I J | 3 |
| G | F H | 1 | F H I J | 2 |
| H | G I J | 1 | F G I J | 2 |
| I | G H J | 2 | F G H J | 3 |
| J | G H I K | 2 | G H I K | 2 |
| K | H J | 3 | G H I J L | 4 |
| L | K M O | 4 | K M N O P R | 5 |
| M | N O P R | 2 | N O P R | 2 |
| N | O Q | 1 | M O P Q R | 2 |
| O | | | | |
| P | | | | |
| Q | | | | |
| R | | | | |
| S | | | | |
| T | | | | |

LOF und kNN

Data Mining
TutorialE. Schubert,
A. ZimekOutlier
detection

Aufgabe 9-2

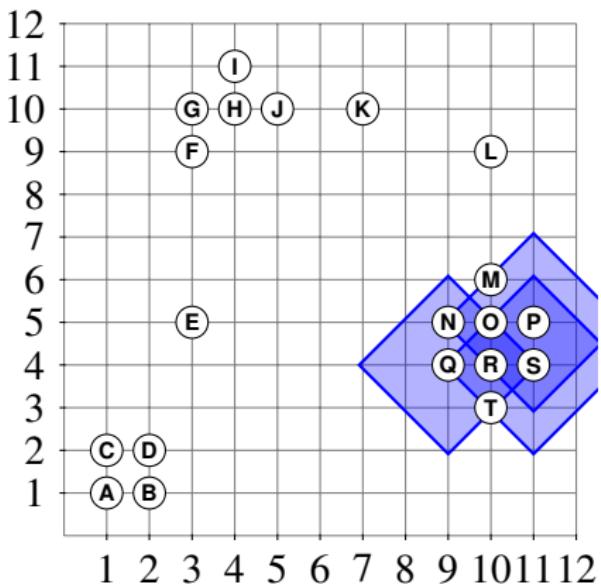


| | 2NN | 2d. | 4NN | 4d. |
|---|---------|-----|-------------|-----|
| A | B C | 1 | B C D E | 6 |
| B | A D | 1 | A C D E | 5 |
| C | A D | 1 | A B D E | 5 |
| D | B C | 1 | A B C E | 4 |
| E | D F | 4 | B C D F G | 5 |
| F | G H | 2 | G H I J | 3 |
| G | F H | 1 | F H I J | 2 |
| H | G I J | 1 | F G I J | 2 |
| I | G H J | 2 | F G H J | 3 |
| J | G H I K | 2 | G H I K | 2 |
| K | H J | 3 | G H I J L | 4 |
| L | K M O | 4 | K M N O P R | 5 |
| M | N O P R | 2 | N O P R | 2 |
| N | O Q | 1 | M O P Q R | 2 |
| O | | | | |
| P | O S | 1 | | |
| Q | N R | 1 | | |
| R | | | | |
| S | P R | 1 | | |
| T | | | | |

LOF und kNN

Data Mining
TutorialE. Schubert,
A. ZimekOutlier
detection

Aufgabe 9-2

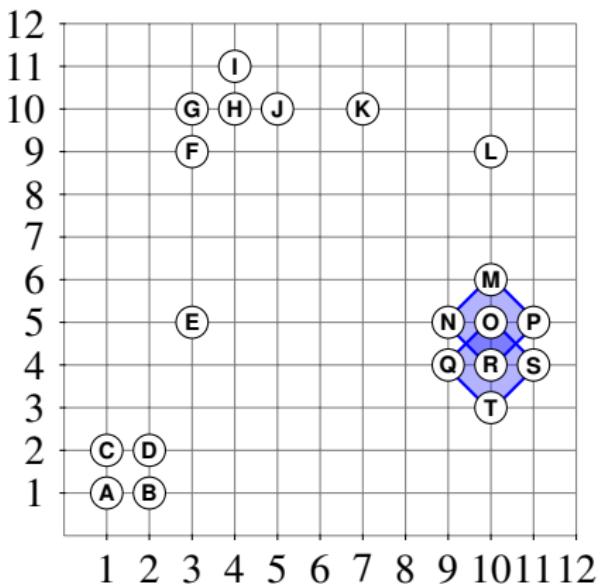


| | 2NN | 2d. | 4NN | 4d. |
|---|---------|-----|-------------|-----|
| A | B C | 1 | B C D E | 6 |
| B | A D | 1 | A C D E | 5 |
| C | A D | 1 | A B D E | 5 |
| D | B C | 1 | A B C E | 4 |
| E | D F | 4 | B C D F G | 5 |
| F | G H | 2 | G H I J | 3 |
| G | F H | 1 | F H I J | 2 |
| H | G I J | 1 | F G I J | 2 |
| I | G H J | 2 | F G H J | 3 |
| J | G H I K | 2 | G H I K | 2 |
| K | H J | 3 | G H I J L | 4 |
| L | K M O | 4 | K M N O P R | 5 |
| M | N O P R | 2 | N O P R | 2 |
| N | O Q | 1 | M O P Q R | 2 |
| O | | | | |
| P | O S | 1 | M N O R S | 2 |
| Q | N R | 1 | N O R S T | 2 |
| R | | | | |
| S | P R | 1 | O P Q R T | 2 |
| T | | | | |

LOF und kNN

Data Mining
TutorialE. Schubert,
A. ZimekOutlier
detection

Aufgabe 9-2

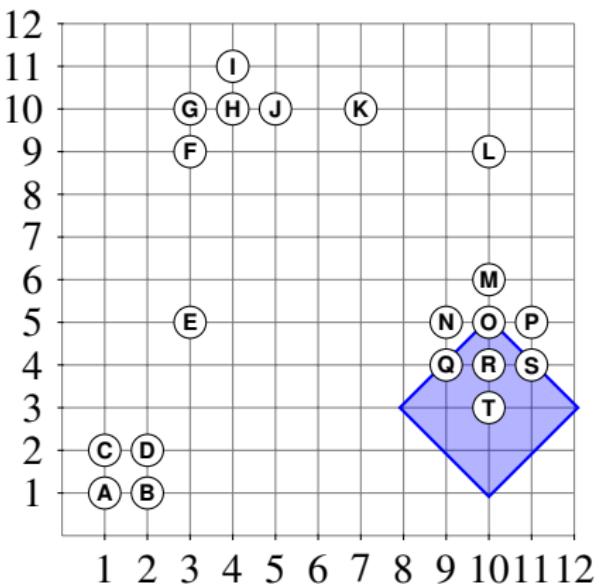


| | 2NN | 2d. | 4NN | 4d. |
|---|---------|-----|-------------|-----|
| A | B C | 1 | B C D E | 6 |
| B | A D | 1 | A C D E | 5 |
| C | A D | 1 | A B D E | 5 |
| D | B C | 1 | A B C E | 4 |
| E | D F | 4 | B C D F G | 5 |
| F | G H | 2 | G H I J | 3 |
| G | F H | 1 | F H I J | 2 |
| H | G I J | 1 | F G I J | 2 |
| I | G H J | 2 | F G H J | 3 |
| J | G H I K | 2 | G H I K | 2 |
| K | H J | 3 | G H I J L | 4 |
| L | K M O | 4 | K M N O P R | 5 |
| M | N O P R | 2 | N O P R | 2 |
| N | O Q | 1 | M O P Q R | 2 |
| O | M N P R | 1 | M N P R | 1 |
| P | O S | 1 | M N O R S | 2 |
| Q | N R | 1 | N O R S T | 2 |
| R | O Q S T | 1 | O Q S T | 1 |
| S | P R | 1 | O P Q R T | 2 |
| T | | | | |

LOF und kNN

Data Mining
TutorialE. Schubert,
A. ZimekOutlier
detection

Aufgabe 9-2



| | 2NN | 2d. | 4NN | 4d. |
|---|---------|-----|-------------|-----|
| A | B C | 1 | B C D E | 6 |
| B | A D | 1 | A C D E | 5 |
| C | A D | 1 | A B D E | 5 |
| D | B C | 1 | A B C E | 4 |
| E | D F | 4 | B C D F G | 5 |
| F | G H | 2 | G H I J | 3 |
| G | F H | 1 | F H I J | 2 |
| H | G I J | 1 | F G I J | 2 |
| I | G H J | 2 | F G H J | 3 |
| J | G H I K | 2 | G H I K | 2 |
| K | H J | 3 | G H I J L | 4 |
| L | K M O | 4 | K M N O P R | 5 |
| M | N O P R | 2 | N O P R | 2 |
| N | O Q | 1 | M O P Q R | 2 |
| O | M N P R | 1 | M N P R | 1 |
| P | O S | 1 | M N O R S | 2 |
| Q | N R | 1 | N O R S T | 2 |
| R | O Q S T | 1 | O Q S T | 1 |
| S | P R | 1 | O P Q R T | 2 |
| T | O Q R S | 2 | O Q R S | 2 |

LOF und k NNData Mining
TutorialE. Schubert,
A. ZimekOutlier
detection

Aufgabe 9-2

| | 2NN | 2d. | 4NN | 4d. | lrd_2 | lrd_4 |
|---|---------|-----|-------------|-----|---------|---------|
| A | B C | 1 | B C D E | 6 | - | - |
| B | A D | 1 | A C D E | 5 | - | - |
| C | A D | 1 | A B D E | 5 | - | - |
| D | B C | 1 | A B C E | 4 | - | - |
| E | D F | 4 | B C D F G | 5 | - | - |
| F | G H | 2 | G H I J | 3 | - | - |
| G | F H | 1 | F H I J | 2 | - | - |
| H | G I J | 1 | F G I J | 2 | - | - |
| I | G H J | 2 | F G H J | 3 | - | - |
| J | G H I K | 2 | G H I K | 2 | - | - |
| K | H J | 3 | G H I J L | 4 | - | - |
| L | K M O | 4 | K M N O P R | 5 | - | - |
| M | N O P R | 2 | N O P R | 2 | - | - |
| N | O Q | 1 | M O P Q R | 2 | - | - |
| O | M N P R | 1 | M N P R | 1 | - | - |
| P | O S | 1 | M N O R S | 2 | - | - |
| Q | N R | 1 | N O R S T | 2 | - | - |
| R | O Q S T | 1 | O Q S T | 1 | - | - |
| S | P R | 1 | O P Q R T | 2 | - | - |
| T | O Q R S | 2 | O Q R S | 2 | - | - |

LOF und k NNData Mining
TutorialE. Schubert,
A. ZimekOutlier
detection

Aufgabe 9-2

| | 2NN | 2d. | 4NN | 4d. | lrd_2 | lrd_4 |
|-----------|-----|-------------|-----|-----------|---------|---------|
| A B C | 1 | B C D E | 6 | - | - | - |
| B A D | 1 | A C D E | 5 | - | - | - |
| C A D | 1 | A B D E | 5 | - | - | - |
| D B C | 1 | A B C E | 4 | - | - | - |
| E D F | 4 | B C D F G | 5 | 2/(4 + 4) | - | - |
| F G H | 2 | G H I J | 3 | - | - | - |
| G F H | 1 | F H I J | 2 | - | - | - |
| H G I J | 1 | F G I J | 2 | - | - | - |
| I G H J | 2 | F G H J | 3 | - | - | - |
| J G H K | 2 | G H I K | 2 | - | - | - |
| K H J | 3 | G H I J L | 4 | - | - | - |
| L K M O | 4 | K M N O P R | 5 | - | - | - |
| M N O P R | 2 | N O P R | 2 | - | - | - |
| N O Q | 1 | M O P Q R | 2 | - | - | - |
| O M N P R | 1 | M N P R | 1 | - | - | - |
| P O S | 1 | M N O R S | 2 | - | - | - |
| Q N R | 1 | N O R S T | 2 | - | - | - |
| R O Q S T | 1 | O Q S T | 1 | - | - | - |
| S P R | 1 | O P Q R T | 2 | - | - | - |
| T O Q R S | 2 | O Q R S | 2 | - | - | - |

LOF und kNN

Data Mining
TutorialE. Schubert,
A. ZimekOutlier
detection

Aufgabe 9-2

| | 2NN | 2d. | 4NN | 4d. | lrd_2 | lrd_4 |
|-----------|-----|-------------|-----|-----------|-----------------------|---------|
| A B C | 1 | B C D E | 6 | - | - | - |
| B A D | 1 | A C D E | 5 | - | - | - |
| C A D | 1 | A B D E | 5 | - | - | - |
| D B C | 1 | A B C E | 4 | - | - | - |
| E D F | 4 | B C D F G | 5 | 2/(4 + 4) | 5/(5 + 5 + 4 + 4 + 5) | - |
| F G H | 2 | G H I J | 3 | - | - | - |
| G F H | 1 | F H I J | 2 | - | - | - |
| H G I J | 1 | F G I J | 2 | - | - | - |
| I G H J | 2 | F G H J | 3 | - | - | - |
| J G H I K | 2 | G H I K | 2 | - | - | - |
| K H J | 3 | G H I J L | 4 | - | - | - |
| L K M O | 4 | K M N O P R | 5 | - | - | - |
| M N O P R | 2 | N O P R | 2 | - | - | - |
| N O Q | 1 | M O P Q R | 2 | - | - | - |
| O M N P R | 1 | M N P R | 1 | - | - | - |
| P O S | 1 | M N O R S | 2 | - | - | - |
| Q N R | 1 | N O R S T | 2 | - | - | - |
| R O Q S T | 1 | O Q S T | 1 | - | - | - |
| S P R | 1 | O P Q R T | 2 | - | - | - |
| T O Q R S | 2 | O Q R S | 2 | - | - | - |

LOF und kNN

Data Mining
TutorialE. Schubert,
A. ZimekOutlier
detection

Aufgabe 9-2

| | 2NN | 2d. | 4NN | 4d. | lrd_2 | lrd_4 |
|---|---------|-----|-------------|-----|-----------|-----------------|
| A | B C | 1 | B C D E | 6 | - | - |
| B | A D | 1 | A C D E | 5 | - | - |
| C | A D | 1 | A B D E | 5 | - | - |
| D | B C | 1 | A B C E | 4 | $2/(1+1)$ | - |
| E | D F | 4 | B C D F G | 5 | $2/(4+4)$ | $5/(5+5+4+4+5)$ |
| F | G H | 2 | G H I J | 3 | - | - |
| G | F H | 1 | F H I J | 2 | - | - |
| H | G I J | 1 | F G I J | 2 | - | - |
| I | G H J | 2 | F G H J | 3 | - | - |
| J | G H I K | 2 | G H I K | 2 | - | - |
| K | H J | 3 | G H I J L | 4 | - | - |
| L | K M O | 4 | K M N O P R | 5 | - | - |
| M | N O P R | 2 | N O P R | 2 | - | - |
| N | O Q | 1 | M O P Q R | 2 | - | - |
| O | M N P R | 1 | M N P R | 1 | - | - |
| P | O S | 1 | M N O R S | 2 | - | - |
| Q | N R | 1 | N O R S T | 2 | - | - |
| R | O Q S T | 1 | O Q S T | 1 | - | - |
| S | P R | 1 | O P Q R T | 2 | - | - |
| T | O Q R S | 2 | O Q R S | 2 | - | - |

LOF und kNN

Data Mining
TutorialE. Schubert,
A. ZimekOutlier
detection

Aufgabe 9-2

| | 2NN | 2d. | 4NN | 4d. | lrd_2 | lrd_4 |
|-----------|-----|-------------|-----|-----------|-----------------|---------|
| A B C | 1 | B C D E | 6 | - | - | - |
| B A D | 1 | A C D E | 5 | - | - | - |
| C A D | 1 | A B D E | 5 | - | - | - |
| D B C | 1 | A B C E | 4 | $2/(1+1)$ | $4/(6+5+5+5)$ | - |
| E D F | 4 | B C D F G | 5 | $2/(4+4)$ | $5/(5+5+4+4+5)$ | - |
| F G H | 2 | G H I J | 3 | - | - | - |
| G F H | 1 | F H I J | 2 | - | - | - |
| H G I J | 1 | F G I J | 2 | - | - | - |
| I G H J | 2 | F G H J | 3 | - | - | - |
| J G H K | 2 | G H I K | 2 | - | - | - |
| K H J | 3 | G H I J L | 4 | - | - | - |
| L K M O | 4 | K M N O P R | 5 | - | - | - |
| M N O P R | 2 | N O P R | 2 | - | - | - |
| N O Q | 1 | M O P Q R | 2 | - | - | - |
| O M N P R | 1 | M N P R | 1 | - | - | - |
| P O S | 1 | M N O R S | 2 | - | - | - |
| Q N R | 1 | N O R S T | 2 | - | - | - |
| R O Q S T | 1 | O Q S T | 1 | - | - | - |
| S P R | 1 | O P Q R T | 2 | - | - | - |
| T O Q R S | 2 | O Q R S | 2 | - | - | - |

LOF und kNN

Data Mining
TutorialE. Schubert,
A. ZimekOutlier
detection

Aufgabe 9-2

| | 2NN | 2d. | 4NN | 4d. | lrd_2 | lrd_4 |
|-----------|-----|-------------|-----|-----------|-----------------|---------|
| A B C | 1 | B C D E | 6 | - | - | - |
| B A D | 1 | A C D E | 5 | - | - | - |
| C A D | 1 | A B D E | 5 | - | - | - |
| D B C | 1 | A B C E | 4 | $2/(1+1)$ | $4/(6+5+5+5)$ | - |
| E D F | 4 | B C D F G | 5 | $2/(4+4)$ | $5/(5+5+4+4+5)$ | - |
| F G H | 2 | G H I J | 3 | $2/(1+2)$ | - | - |
| G F H | 1 | F H I J | 2 | - | - | - |
| H G I J | 1 | F G I J | 2 | - | - | - |
| I G H J | 2 | F G H J | 3 | - | - | - |
| J G H K | 2 | G H I K | 2 | - | - | - |
| K H J | 3 | G H I J L | 4 | - | - | - |
| L K M O | 4 | K M N O P R | 5 | - | - | - |
| M N O P R | 2 | N O P R | 2 | - | - | - |
| N O Q | 1 | M O P Q R | 2 | - | - | - |
| O M N P R | 1 | M N P R | 1 | - | - | - |
| P O S | 1 | M N O R S | 2 | - | - | - |
| Q N R | 1 | N O R S T | 2 | - | - | - |
| R O Q S T | 1 | O Q S T | 1 | - | - | - |
| S P R | 1 | O P Q R T | 2 | - | - | - |
| T O Q R S | 2 | O Q R S | 2 | - | - | - |

LOF und kNN

Data Mining
TutorialE. Schubert,
A. ZimekOutlier
detection

Aufgabe 9-2

| 2NN | 2d. | 4NN | 4d. | lrd_2 | lrd_4 |
|-----------|-----|-------------|-----|-----------|-----------------|
| A B C | 1 | B C D E | 6 | - | - |
| B A D | 1 | A C D E | 5 | - | - |
| C A D | 1 | A B D E | 5 | - | - |
| D B C | 1 | A B C E | 4 | $2/(1+1)$ | $4/(6+5+5+5)$ |
| E D F | 4 | B C D F G | 5 | $2/(4+4)$ | $5/(5+5+4+4+5)$ |
| F G H | 2 | G H I J | 3 | $2/(1+2)$ | $4/(2+2+3+3)$ |
| G F H | 1 | F H I J | 2 | - | - |
| H G I J | 1 | F G I J | 2 | - | - |
| I G H J | 2 | F G H J | 3 | - | - |
| J G H I K | 2 | G H I K | 2 | - | - |
| K H J | 3 | G H I J L | 4 | - | - |
| L K M O | 4 | K M N O P R | 5 | - | - |
| M N O P R | 2 | N O P R | 2 | - | - |
| N O Q | 1 | M O P Q R | 2 | - | - |
| O M N P R | 1 | M N P R | 1 | - | - |
| P O S | 1 | M N O R S | 2 | - | - |
| Q N R | 1 | N O R S T | 2 | - | - |
| R O Q S T | 1 | O Q S T | 1 | - | - |
| S P R | 1 | O P Q R T | 2 | - | - |
| T O Q R S | 2 | O Q R S | 2 | - | - |

LOF und kNN

Data Mining
TutorialE. Schubert,
A. ZimekOutlier
detection

Aufgabe 9-2

| 2NN | 2d. | 4NN | 4d. | lrd_2 | lrd_4 |
|-----------|-----|-------------|-----|-------------|-------------------------|
| A B C | 1 | B C D E | 6 | - | - |
| B A D | 1 | A C D E | 5 | - | $4/(6 + 5 + 4 + 5)$ |
| C A D | 1 | A B D E | 5 | - | |
| D B C | 1 | A B C E | 4 | $2/(1 + 1)$ | $4/(6 + 5 + 5 + 5)$ |
| E D F | 4 | B C D F G | 5 | $2/(4 + 4)$ | $5/(5 + 5 + 4 + 4 + 5)$ |
| F G H | 2 | G H I J | 3 | $2/(1 + 2)$ | $4/(2 + 2 + 3 + 3)$ |
| G F H | 1 | F H I J | 2 | - | |
| H G I J | 1 | F G I J | 2 | | |
| I G H J | 2 | F G H J | 3 | - | |
| J G H I K | 2 | G H I K | 2 | | |
| K H J | 3 | G H I J L | 4 | | |
| L K M O | 4 | K M N O P R | 5 | - | |
| M N O P R | 2 | N O P R | 2 | | |
| N O Q | 1 | M O P Q R | 2 | | |
| O M N P R | 1 | M N P R | 1 | | |
| P O S | 1 | M N O R S | 2 | | |
| Q N R | 1 | N O R S T | 2 | - | |
| R O Q S T | 1 | O Q S T | 1 | | |
| S P R | 1 | O P Q R T | 2 | - | |
| T O Q R S | 2 | O Q R S | 2 | - | |

LOF und kNN

Data Mining
TutorialE. Schubert,
A. ZimekOutlier
detection

Aufgabe 9-2

| 2NN | 2d. | 4NN | 4d. | lrd_2 | lrd_4 |
|-----------|-----|-------------|-----|-------------|-------------------------|
| A B C | 1 | B C D E | 6 | - | - |
| B A D | 1 | A C D E | 5 | - | $4/(6 + 5 + 4 + 5)$ |
| C A D | 1 | A B D E | 5 | - | $4/(6 + 5 + 4 + 5)$ |
| D B C | 1 | A B C E | 4 | $2/(1 + 1)$ | $4/(6 + 5 + 5 + 5)$ |
| E D F | 4 | B C D F G | 5 | $2/(4 + 4)$ | $5/(5 + 5 + 4 + 4 + 5)$ |
| F G H | 2 | G H I J | 3 | $2/(1 + 2)$ | $4/(2 + 2 + 3 + 3)$ |
| G F H | 1 | F H I J | 2 | - | |
| H G I J | 1 | F G I J | 2 | | |
| I G H J | 2 | F G H J | 3 | - | |
| J G H I K | 2 | G H I K | 2 | | |
| K H J | 3 | G H I J L | 4 | | |
| L K M O | 4 | K M N O P R | 5 | - | |
| M N O P R | 2 | N O P R | 2 | | |
| N O Q | 1 | M O P Q R | 2 | | |
| O M N P R | 1 | M N P R | 1 | | |
| P O S | 1 | M N O R S | 2 | | |
| Q N R | 1 | N O R S T | 2 | - | |
| R O Q S T | 1 | O Q S T | 1 | | |
| S P R | 1 | O P Q R T | 2 | - | |
| T O Q R S | 2 | O Q R S | 2 | - | |

LOF und kNN

Data Mining
TutorialE. Schubert,
A. ZimekOutlier
detection

Aufgabe 9-2

| 2NN | 2d. | 4NN | 4d. | lrd_2 | lrd_4 |
|-----------|-----|-------------|-----|-------------|-------------------------|
| A B C | 1 | B C D E | 6 | - | - |
| B A D | 1 | A C D E | 5 | - | $4/(6 + 5 + 4 + 5)$ |
| C A D | 1 | A B D E | 5 | - | $4/(6 + 5 + 4 + 5)$ |
| D B C | 1 | A B C E | 4 | $2/(1 + 1)$ | $4/(6 + 5 + 5 + 5)$ |
| E D F | 4 | B C D F G | 5 | $2/(4 + 4)$ | $5/(5 + 5 + 4 + 4 + 5)$ |
| F G H | 2 | G H I J | 3 | $2/(1 + 2)$ | $4/(2 + 2 + 3 + 3)$ |
| G F H | 1 | F H I J | 2 | - | $4/(3 + 2 + 3 + 2)$ |
| H G I J | 1 | F G I J | 2 | | |
| I G H J | 2 | F G H J | 3 | - | |
| J G H I K | 2 | G H I K | 2 | | |
| K H J | 3 | G H I J L | 4 | | |
| L K M O | 4 | K M N O P R | 5 | - | |
| M N O P R | 2 | N O P R | 2 | | |
| N O Q | 1 | M O P Q R | 2 | | |
| O M N P R | 1 | M N P R | 1 | | |
| P O S | 1 | M N O R S | 2 | | |
| Q N R | 1 | N O R S T | 2 | - | |
| R O Q S T | 1 | O Q S T | 1 | | |
| S P R | 1 | O P Q R T | 2 | - | |
| T O Q R S | 2 | O Q R S | 2 | - | |

LOF und kNN

Data Mining
TutorialE. Schubert,
A. ZimekOutlier
detection

Aufgabe 9-2

| 2NN | 2d. | 4NN | 4d. | lrd_2 | lrd_4 |
|-----------|-----|-------------|-----|-------------|-------------------------|
| A B C | 1 | B C D E | 6 | - | - |
| B A D | 1 | A C D E | 5 | - | $4/(6 + 5 + 4 + 5)$ |
| C A D | 1 | A B D E | 5 | - | $4/(6 + 5 + 4 + 5)$ |
| D B C | 1 | A B C E | 4 | $2/(1 + 1)$ | $4/(6 + 5 + 5 + 5)$ |
| E D F | 4 | B C D F G | 5 | $2/(4 + 4)$ | $5/(5 + 5 + 4 + 4 + 5)$ |
| F G H | 2 | G H I J | 3 | $2/(1 + 2)$ | $4/(2 + 2 + 3 + 3)$ |
| G F H | 1 | F H I J | 2 | - | $4/(3 + 2 + 3 + 2)$ |
| H G I J | 1 | F G I J | 2 | | |
| I G H J | 2 | F G H J | 3 | - | |
| J G H I K | 2 | G H I K | 2 | | |
| K H J | 3 | G H I J L | 4 | $2/(2 + 3)$ | |
| L K M O | 4 | K M N O P R | 5 | - | |
| M N O P R | 2 | N O P R | 2 | | |
| N O Q | 1 | M O P Q R | 2 | | |
| O M N P R | 1 | M N P R | 1 | | |
| P O S | 1 | M N O R S | 2 | | |
| Q N R | 1 | N O R S T | 2 | - | |
| R O Q S T | 1 | O Q S T | 1 | | |
| S P R | 1 | O P Q R T | 2 | - | |
| T O Q R S | 2 | O Q R S | 2 | - | |

LOF und kNN

Data Mining
TutorialE. Schubert,
A. ZimekOutlier
detection

Aufgabe 9-2

| 2NN | 2d. | 4NN | 4d. | lrd_2 | lrd_4 |
|-----------|-----|-------------|-----|-------------|-------------------------|
| A B C | 1 | B C D E | 6 | - | - |
| B A D | 1 | A C D E | 5 | - | $4/(6 + 5 + 4 + 5)$ |
| C A D | 1 | A B D E | 5 | - | $4/(6 + 5 + 4 + 5)$ |
| D B C | 1 | A B C E | 4 | $2/(1 + 1)$ | $4/(6 + 5 + 5 + 5)$ |
| E D F | 4 | B C D F G | 5 | $2/(4 + 4)$ | $5/(5 + 5 + 4 + 4 + 5)$ |
| F G H | 2 | G H I J | 3 | $2/(1 + 2)$ | $4/(2 + 2 + 3 + 3)$ |
| G F H | 1 | F H I J | 2 | - | $4/(3 + 2 + 3 + 2)$ |
| H G I J | 1 | F G I J | 2 | | |
| I G H J | 2 | F G H J | 3 | - | |
| J G H I K | 2 | G H I K | 2 | | |
| K H J | 3 | G H I J L | 4 | $2/(2 + 3)$ | $5/(4 + 3 + 4 + 2 + 5)$ |
| L K M O | 4 | K M N O P R | 5 | - | |
| M N O P R | 2 | N O P R | 2 | | |
| N O Q | 1 | M O P Q R | 2 | | |
| O M N P R | 1 | M N P R | 1 | | |
| P O S | 1 | M N O R S | 2 | | |
| Q N R | 1 | N O R S T | 2 | - | |
| R O Q S T | 1 | O Q S T | 1 | | |
| S P R | 1 | O P Q R T | 2 | - | |
| T O Q R S | 2 | O Q R S | 2 | - | - |

| 2NN | 2d. | 4NN | 4d. | lrd_2 | lrd_4 |
|-----------|-----|-------------|-----|-----------------|-------------------------|
| A B C | 1 | B C D E | 6 | - | - |
| B A D | 1 | A C D E | 5 | - | $4/(6 + 5 + 4 + 5)$ |
| C A D | 1 | A B D E | 5 | - | $4/(6 + 5 + 4 + 5)$ |
| D B C | 1 | A B C E | 4 | $2/(1 + 1)$ | $4/(6 + 5 + 5 + 5)$ |
| E D F | 4 | B C D F G | 5 | $2/(4 + 4)$ | $5/(5 + 5 + 4 + 4 + 5)$ |
| F G H | 2 | G H I J | 3 | $2/(1 + 2)$ | $4/(2 + 2 + 3 + 3)$ |
| G F H | 1 | F H I J | 2 | - | $4/(3 + 2 + 3 + 2)$ |
| H G I J | 1 | F G I J | 2 | $3/(1 + 2 + 2)$ | |
| I G H J | 2 | F G H J | 3 | - | |
| J G H I K | 2 | G H I K | 2 | | |
| K H J | 3 | G H I J L | 4 | $2/(2 + 3)$ | $5/(4 + 3 + 4 + 2 + 5)$ |
| L K M O | 4 | K M N O P R | 5 | - | |
| M N O P R | 2 | N O P R | 2 | | |
| N O Q | 1 | M O P Q R | 2 | | |
| O M N P R | 1 | M N P R | 1 | | |
| P O S | 1 | M N O R S | 2 | | |
| Q N R | 1 | N O R S T | 2 | - | |
| R O Q S T | 1 | O Q S T | 1 | | |
| S P R | 1 | O P Q R T | 2 | - | |
| T O Q R S | 2 | O Q R S | 2 | - | - |

| 2NN | 2d. | 4NN | 4d. | lrd_2 | lrd_4 |
|-----------|-----|-------------|-----|-----------------|-------------------------|
| A B C | 1 | B C D E | 6 | - | - |
| B A D | 1 | A C D E | 5 | - | $4/(6 + 5 + 4 + 5)$ |
| C A D | 1 | A B D E | 5 | - | $4/(6 + 5 + 4 + 5)$ |
| D B C | 1 | A B C E | 4 | $2/(1 + 1)$ | $4/(6 + 5 + 5 + 5)$ |
| E D F | 4 | B C D F G | 5 | $2/(4 + 4)$ | $5/(5 + 5 + 4 + 4 + 5)$ |
| F G H | 2 | G H I J | 3 | $2/(1 + 2)$ | $4/(2 + 2 + 3 + 3)$ |
| G F H | 1 | F H I J | 2 | - | $4/(3 + 2 + 3 + 2)$ |
| H G I J | 1 | F G I J | 2 | $3/(1 + 2 + 2)$ | $4/(3 + 2 + 3 + 2)$ |
| I G H J | 2 | F G H J | 3 | - | |
| J G H I K | 2 | G H I K | 2 | | |
| K H J | 3 | G H I J L | 4 | $2/(2 + 3)$ | $5/(4 + 3 + 4 + 2 + 5)$ |
| L K M O | 4 | K M N O P R | 5 | - | |
| M N O P R | 2 | N O P R | 2 | | |
| N O Q | 1 | M O P Q R | 2 | | |
| O M N P R | 1 | M N P R | 1 | | |
| P O S | 1 | M N O R S | 2 | | |
| Q N R | 1 | N O R S T | 2 | - | |
| R O Q S T | 1 | O Q S T | 1 | | |
| S P R | 1 | O P Q R T | 2 | - | |
| T O Q R S | 2 | O Q R S | 2 | - | |

| 2NN | 2d. | 4NN | 4d. | lrd_2 | lrd_4 |
|-----------|-----|-------------|-----|---------------------|-------------------------|
| A B C | 1 | B C D E | 6 | - | - |
| B A D | 1 | A C D E | 5 | - | $4/(6 + 5 + 4 + 5)$ |
| C A D | 1 | A B D E | 5 | - | $4/(6 + 5 + 4 + 5)$ |
| D B C | 1 | A B C E | 4 | $2/(1 + 1)$ | $4/(6 + 5 + 5 + 5)$ |
| E D F | 4 | B C D F G | 5 | $2/(4 + 4)$ | $5/(5 + 5 + 4 + 4 + 5)$ |
| F G H | 2 | G H I J | 3 | $2/(1 + 2)$ | $4/(2 + 2 + 3 + 3)$ |
| G F H | 1 | F H I J | 2 | - | $4/(3 + 2 + 3 + 2)$ |
| H G I J | 1 | F G I J | 2 | $3/(1 + 2 + 2)$ | $4/(3 + 2 + 3 + 2)$ |
| I G H J | 2 | F G H J | 3 | - | |
| J G H I K | 2 | G H I K | 2 | $4/(2 + 1 + 2 + 3)$ | |
| K H J | 3 | G H I J L | 4 | $2/(2 + 3)$ | $5/(4 + 3 + 4 + 2 + 5)$ |
| L K M O | 4 | K M N O P R | 5 | - | |
| M N O P R | 2 | N O P R | 2 | | |
| N O Q | 1 | M O P Q R | 2 | | |
| O M N P R | 1 | M N P R | 1 | | |
| P O S | 1 | M N O R S | 2 | | |
| Q N R | 1 | N O R S T | 2 | - | |
| R O Q S T | 1 | O Q S T | 1 | | |
| S P R | 1 | O P Q R T | 2 | - | |
| T O Q R S | 2 | O Q R S | 2 | - | |

| | 2NN | 2d. | 4NN | 4d. | lrd_2 | lrd_4 |
|-----------|-----|-------------|-----|---------------------|-------------------------|-------------------------|
| A B C | 1 | B C D E | 6 | - | - | - |
| B A D | 1 | A C D E | 5 | - | $4/(6 + 5 + 4 + 5)$ | $4/(6 + 5 + 4 + 5)$ |
| C A D | 1 | A B D E | 5 | - | $4/(6 + 5 + 4 + 5)$ | $4/(6 + 5 + 4 + 5)$ |
| D B C | 1 | A B C E | 4 | $2/(1 + 1)$ | $4/(6 + 5 + 5 + 5)$ | $5/(5 + 5 + 4 + 4 + 5)$ |
| E D F | 4 | B C D F G | 5 | $2/(4 + 4)$ | $4/(2 + 2 + 3 + 3)$ | $4/(3 + 2 + 3 + 2)$ |
| F G H | 2 | G H I J | 3 | $2/(1 + 2)$ | $4/(3 + 2 + 3 + 2)$ | $4/(3 + 2 + 3 + 2)$ |
| G F H | 1 | F H I J | 2 | - | $4/(2 + 2 + 3 + 3)$ | $4/(2 + 2 + 3 + 3)$ |
| H G I J | 1 | F G I J | 2 | $3/(1 + 2 + 2)$ | $4/(2 + 2 + 3 + 4)$ | $4/(2 + 2 + 3 + 4)$ |
| I G H J | 2 | F G H J | 3 | - | $5/(4 + 3 + 4 + 2 + 5)$ | $5/(4 + 3 + 4 + 2 + 5)$ |
| J G H I K | 2 | G H I K | 2 | $4/(2 + 1 + 2 + 3)$ | - | - |
| K H J | 3 | G H I J L | 4 | $2/(2 + 3)$ | - | - |
| L K M O | 4 | K M N O P R | 5 | - | - | - |
| M N O P R | 2 | N O P R | 2 | - | - | - |
| N O Q | 1 | M O P Q R | 2 | - | - | - |
| O M N P R | 1 | M N P R | 1 | - | - | - |
| P O S | 1 | M N O R S | 2 | - | - | - |
| Q N R | 1 | N O R S T | 2 | - | - | - |
| R O Q S T | 1 | O Q S T | 1 | - | - | - |
| S P R | 1 | O P Q R T | 2 | - | - | - |
| T O Q R S | 2 | O Q R S | 2 | - | - | - |

| 2NN | 2d. | 4NN | 4d. | lrd_2 | lrd_4 |
|-----------|-----|-------------|-----|---------------------|-------------------------|
| A B C | 1 | B C D E | 6 | - | - |
| B A D | 1 | A C D E | 5 | - | $4/(6 + 5 + 4 + 5)$ |
| C A D | 1 | A B D E | 5 | - | $4/(6 + 5 + 4 + 5)$ |
| D B C | 1 | A B C E | 4 | $2/(1 + 1)$ | $4/(6 + 5 + 5 + 5)$ |
| E D F | 4 | B C D F G | 5 | $2/(4 + 4)$ | $5/(5 + 5 + 4 + 4 + 5)$ |
| F G H | 2 | G H I J | 3 | $2/(1 + 2)$ | $4/(2 + 2 + 3 + 3)$ |
| G F H | 1 | F H I J | 2 | - | $4/(3 + 2 + 3 + 2)$ |
| H G I J | 1 | F G I J | 2 | $3/(1 + 2 + 2)$ | $4/(3 + 2 + 3 + 2)$ |
| I G H J | 2 | F G H J | 3 | - | $4/(3 + 2 + 2 + 2)$ |
| J G H I K | 2 | G H I K | 2 | $4/(2 + 1 + 2 + 3)$ | $4/(2 + 2 + 3 + 4)$ |
| K H J | 3 | G H I J L | 4 | $2/(2 + 3)$ | $5/(4 + 3 + 4 + 2 + 5)$ |
| L K M O | 4 | K M N O P R | 5 | - | |
| M N O P R | 2 | N O P R | 2 | | |
| N O Q | 1 | M O P Q R | 2 | | |
| O M N P R | 1 | M N P R | 1 | | |
| P O S | 1 | M N O R S | 2 | | |
| Q N R | 1 | N O R S T | 2 | - | |
| R O Q S T | 1 | O Q S T | 1 | | |
| S P R | 1 | O P Q R T | 2 | - | |
| T O Q R S | 2 | O Q R S | 2 | - | |

| 2NN | 2d. | 4NN | 4d. | lrd_2 | lrd_4 |
|-----------|-----|-------------|-----|---------------------|-----------------------------|
| A B C | 1 | B C D E | 6 | - | - |
| B A D | 1 | A C D E | 5 | - | $4/(6 + 5 + 4 + 5)$ |
| C A D | 1 | A B D E | 5 | - | $4/(6 + 5 + 4 + 5)$ |
| D B C | 1 | A B C E | 4 | $2/(1 + 1)$ | $4/(6 + 5 + 5 + 5)$ |
| E D F | 4 | B C D F G | 5 | $2/(4 + 4)$ | $5/(5 + 5 + 4 + 4 + 5)$ |
| F G H | 2 | G H I J | 3 | $2/(1 + 2)$ | $4/(2 + 2 + 3 + 3)$ |
| G F H | 1 | F H I J | 2 | - | $4/(3 + 2 + 3 + 2)$ |
| H G I J | 1 | F G I J | 2 | $3/(1 + 2 + 2)$ | $4/(3 + 2 + 3 + 2)$ |
| I G H J | 2 | F G H J | 3 | - | $4/(3 + 2 + 2 + 2)$ |
| J G H I K | 2 | G H I K | 2 | $4/(2 + 1 + 2 + 3)$ | $4/(2 + 2 + 3 + 4)$ |
| K H J | 3 | G H I J L | 4 | $2/(2 + 3)$ | $5/(4 + 3 + 4 + 2 + 5)$ |
| L K M O | 4 | K M N O P R | 5 | - | $6/(4 + 3 + 5 + 4 + 5 + 5)$ |
| M N O P R | 2 | N O P R | 2 | | |
| N O Q | 1 | M O P Q R | 2 | | |
| O M N P R | 1 | M N P R | 1 | | |
| P O S | 1 | M N O R S | 2 | | |
| Q N R | 1 | N O R S T | 2 | - | - |
| R O Q S T | 1 | O Q S T | 1 | - | - |
| S P R | 1 | O P Q R T | 2 | - | - |
| T O Q R S | 2 | O Q R S | 2 | - | - |

| | 2NN | 2d. | 4NN | 4d. | lrd_2 | lrd_4 |
|-----------|-----|-------------|-----|---------------------|-----------------------------|-----------------------------|
| A B C | 1 | B C D E | 6 | - | - | - |
| B A D | 1 | A C D E | 5 | - | $4/(6 + 5 + 4 + 5)$ | $4/(6 + 5 + 4 + 5)$ |
| C A D | 1 | A B D E | 5 | - | $4/(6 + 5 + 4 + 5)$ | $4/(6 + 5 + 4 + 5)$ |
| D B C | 1 | A B C E | 4 | $2/(1 + 1)$ | $4/(6 + 5 + 5 + 5)$ | $5/(5 + 5 + 4 + 4 + 5)$ |
| E D F | 4 | B C D F G | 5 | $2/(4 + 4)$ | $4/(2 + 2 + 3 + 3)$ | $4/(3 + 2 + 3 + 2)$ |
| F G H | 2 | G H I J | 3 | $2/(1 + 2)$ | $4/(3 + 2 + 3 + 2)$ | $4/(3 + 2 + 2 + 2)$ |
| G F H | 1 | F H I J | 2 | - | $4/(2 + 2 + 3 + 3)$ | $4/(2 + 2 + 2 + 2)$ |
| H G I J | 1 | F G I J | 2 | $3/(1 + 2 + 2)$ | $4/(2 + 2 + 3 + 4)$ | $5/(4 + 3 + 4 + 2 + 5)$ |
| I G H J | 2 | F G H J | 3 | - | $6/(4 + 3 + 5 + 4 + 5 + 5)$ | $6/(4 + 3 + 5 + 4 + 5 + 5)$ |
| J G H I K | 2 | G H I K | 2 | $4/(2 + 1 + 2 + 3)$ | - | - |
| K H J | 3 | G H I J L | 4 | $2/(2 + 3)$ | - | - |
| L K M O R | 4 | K M N O P R | 5 | - | - | - |
| M N O P R | 2 | N O P R | 2 | - | - | - |
| N O Q | 1 | M O P Q R | 2 | - | - | - |
| O M N P R | 1 | M N P R | 1 | $4/(2 + 1 + 1 + 1)$ | - | - |
| P O S | 1 | M N O R S | 2 | - | - | - |
| Q N R | 1 | N O R S T | 2 | - | - | - |
| R O Q S T | 1 | O Q S T | 1 | - | - | - |
| S P R | 1 | O P Q R T | 2 | - | - | - |
| T O Q R S | 2 | O Q R S | 2 | - | - | - |

| | 2NN | 2d. | 4NN | 4d. | lrd_2 | lrd_4 |
|-----------|-----|-------------|-----|---------------------|-----------------------------|-----------------------------|
| A B C | 1 | B C D E | 6 | - | - | - |
| B A D | 1 | A C D E | 5 | - | $4/(6 + 5 + 4 + 5)$ | $4/(6 + 5 + 4 + 5)$ |
| C A D | 1 | A B D E | 5 | - | $4/(6 + 5 + 4 + 5)$ | $4/(6 + 5 + 4 + 5)$ |
| D B C | 1 | A B C E | 4 | $2/(1 + 1)$ | $4/(6 + 5 + 5 + 5)$ | $5/(5 + 5 + 4 + 4 + 5)$ |
| E D F | 4 | B C D F G | 5 | $2/(4 + 4)$ | $4/(2 + 2 + 3 + 3)$ | $4/(3 + 2 + 3 + 2)$ |
| F G H | 2 | G H I J | 3 | $2/(1 + 2)$ | $4/(3 + 2 + 3 + 2)$ | $4/(3 + 2 + 2 + 2)$ |
| G F H | 1 | F H I J | 2 | - | $4/(2 + 2 + 3 + 3)$ | $4/(2 + 2 + 2 + 2)$ |
| H G I J | 1 | F G I J | 2 | $3/(1 + 2 + 2)$ | $4/(2 + 2 + 3 + 4)$ | $5/(4 + 3 + 4 + 2 + 5)$ |
| I G H J | 2 | F G H J | 3 | - | $6/(4 + 3 + 5 + 4 + 5 + 5)$ | $6/(4 + 3 + 5 + 4 + 5 + 5)$ |
| J G H I K | 2 | G H I K | 2 | $4/(2 + 1 + 2 + 3)$ | $4/(2 + 2 + 2 + 1)$ | $4/(2 + 2 + 2 + 1)$ |
| K H J | 3 | G H I J L | 4 | $2/(2 + 3)$ | $4/(2 + 2 + 2 + 1)$ | $4/(2 + 2 + 2 + 1)$ |
| L K M O | 4 | K M N O P R | 5 | - | $4/(2 + 2 + 2 + 1)$ | $4/(2 + 2 + 2 + 1)$ |
| M N O P R | 2 | N O P R | 2 | - | $4/(2 + 2 + 2 + 1)$ | $4/(2 + 2 + 2 + 1)$ |
| N O Q | 1 | M O P Q R | 2 | - | $4/(2 + 2 + 2 + 1)$ | $4/(2 + 2 + 2 + 1)$ |
| O M N P R | 1 | M N P R | 1 | $4/(2 + 1 + 1 + 1)$ | $4/(2 + 2 + 2 + 1)$ | $4/(2 + 2 + 2 + 1)$ |
| P O S | 1 | M N O R S | 2 | - | $4/(2 + 2 + 2 + 1)$ | $4/(2 + 2 + 2 + 1)$ |
| Q N R | 1 | N O R S T | 2 | - | $4/(2 + 2 + 2 + 1)$ | $4/(2 + 2 + 2 + 1)$ |
| R O Q S T | 1 | O Q S T | 1 | - | $4/(2 + 2 + 2 + 1)$ | $4/(2 + 2 + 2 + 1)$ |
| S P R | 1 | O P Q R T | 2 | - | $4/(2 + 2 + 2 + 1)$ | $4/(2 + 2 + 2 + 1)$ |
| T O Q R S | 2 | O Q R S | 2 | - | $4/(2 + 2 + 2 + 1)$ | $4/(2 + 2 + 2 + 1)$ |

| | 2NN | 2d. | 4NN | 4d. | lrd_2 | lrd_4 |
|-----------|-----|-------------|-----|---------------------|-----------------------------|-----------------------------|
| A B C | 1 | B C D E | 6 | - | - | - |
| B A D | 1 | A C D E | 5 | - | $4/(6 + 5 + 4 + 5)$ | $4/(6 + 5 + 4 + 5)$ |
| C A D | 1 | A B D E | 5 | - | $4/(6 + 5 + 4 + 5)$ | $4/(6 + 5 + 4 + 5)$ |
| D B C | 1 | A B C E | 4 | $2/(1 + 1)$ | $4/(6 + 5 + 5 + 5)$ | $5/(5 + 5 + 4 + 4 + 5)$ |
| E D F | 4 | B C D F G | 5 | $2/(4 + 4)$ | $4/(2 + 2 + 3 + 3)$ | $4/(3 + 2 + 3 + 2)$ |
| F G H | 2 | G H I J | 3 | $2/(1 + 2)$ | $4/(3 + 2 + 3 + 2)$ | $4/(3 + 2 + 2 + 2)$ |
| G F H | 1 | F H I J | 2 | - | $4/(2 + 2 + 3 + 3)$ | $4/(2 + 2 + 2 + 2)$ |
| H G I J | 1 | F G I J | 2 | $3/(1 + 2 + 2)$ | $4/(2 + 2 + 3 + 4)$ | $5/(4 + 3 + 4 + 2 + 5)$ |
| I G H J | 2 | F G H J | 3 | - | $6/(4 + 3 + 5 + 4 + 5 + 5)$ | $6/(4 + 3 + 5 + 4 + 5 + 5)$ |
| J G H I K | 2 | G H I K | 2 | $4/(2 + 1 + 2 + 3)$ | $4/(2 + 2 + 2 + 2)$ | $4/(2 + 2 + 1 + 2)$ |
| K H J | 3 | G H I J L | 4 | $2/(2 + 3)$ | $4/(2 + 2 + 1 + 2)$ | $4/(2 + 2 + 1 + 2)$ |
| L K M O | 4 | K M N O P R | 5 | - | $4/(2 + 2 + 1 + 2)$ | $4/(2 + 2 + 1 + 2)$ |
| M N O P R | 2 | N O P R | 2 | $4/(2 + 2 + 1 + 2)$ | $4/(2 + 2 + 1 + 2)$ | $4/(2 + 2 + 1 + 2)$ |
| N O Q | 1 | M O P Q R | 2 | - | $4/(2 + 2 + 1 + 2)$ | $4/(2 + 2 + 1 + 2)$ |
| O M N P R | 1 | M N P R | 1 | $4/(2 + 1 + 1 + 1)$ | $4/(2 + 2 + 2 + 1)$ | $4/(2 + 2 + 2 + 1)$ |
| P O S | 1 | M N O R S | 2 | - | $4/(2 + 2 + 2 + 1)$ | $4/(2 + 2 + 2 + 1)$ |
| Q N R | 1 | N O R S T | 2 | - | $4/(2 + 2 + 2 + 1)$ | $4/(2 + 2 + 2 + 1)$ |
| R O Q S T | 1 | O Q S T | 1 | - | $4/(2 + 2 + 2 + 1)$ | $4/(2 + 2 + 2 + 1)$ |
| S P R | 1 | O P Q R T | 2 | - | $4/(2 + 2 + 2 + 1)$ | $4/(2 + 2 + 2 + 1)$ |
| T O Q R S | 2 | O Q R S | 2 | - | $4/(2 + 2 + 2 + 1)$ | $4/(2 + 2 + 2 + 1)$ |

| | 2NN | 2d. | 4NN | 4d. | lrd_2 | lrd_4 |
|-----------|-----|-------------|-----|---------------------|-----------------------------|-----------------------------|
| A B C | 1 | B C D E | 6 | - | - | - |
| B A D | 1 | A C D E | 5 | - | $4/(6 + 5 + 4 + 5)$ | $4/(6 + 5 + 4 + 5)$ |
| C A D | 1 | A B D E | 5 | - | $4/(6 + 5 + 4 + 5)$ | $4/(6 + 5 + 4 + 5)$ |
| D B C | 1 | A B C E | 4 | $2/(1 + 1)$ | $4/(6 + 5 + 5 + 5)$ | $5/(5 + 5 + 4 + 4 + 5)$ |
| E D F | 4 | B C D F G | 5 | $2/(4 + 4)$ | $4/(2 + 2 + 3 + 3)$ | $4/(3 + 2 + 3 + 2)$ |
| F G H | 2 | G H I J | 3 | $2/(1 + 2)$ | $4/(3 + 2 + 3 + 2)$ | $4/(3 + 2 + 2 + 2)$ |
| G F H | 1 | F H I J | 2 | - | $4/(2 + 2 + 3 + 3)$ | $4/(2 + 2 + 2 + 2)$ |
| H G I J | 1 | F G I J | 2 | $3/(1 + 2 + 2)$ | $4/(2 + 2 + 3 + 4)$ | $5/(4 + 3 + 4 + 2 + 5)$ |
| I G H J | 2 | F G H J | 3 | - | $6/(4 + 3 + 5 + 4 + 5 + 5)$ | $6/(4 + 3 + 5 + 4 + 5 + 5)$ |
| J G H I K | 2 | G H I K | 2 | $4/(2 + 1 + 2 + 3)$ | $4/(2 + 2 + 2 + 2)$ | $4/(2 + 2 + 2 + 2)$ |
| K H J | 3 | G H I J L | 4 | $2/(2 + 3)$ | $4/(2 + 2 + 2 + 1)$ | $4/(2 + 2 + 2 + 1)$ |
| L K M O R | 4 | K M N O P R | 5 | - | $4/(2 + 2 + 2 + 1 + 2)$ | $4/(2 + 2 + 2 + 1 + 2)$ |
| M N O P R | 2 | N O P R | 2 | $4/(2 + 2 + 1 + 2)$ | $4/(2 + 1 + 2 + 2)$ | $4/(2 + 1 + 2 + 2)$ |
| N O Q | 1 | M O P Q R | 2 | - | - | - |
| O M N P R | 1 | M N P R | 1 | $4/(2 + 1 + 1 + 1)$ | $4/(2 + 2 + 2 + 1)$ | $4/(2 + 2 + 2 + 1)$ |
| P O S | 1 | M N O R S | 2 | - | - | - |
| Q N R | 1 | N O R S T | 2 | - | - | - |
| R O Q S T | 1 | O Q S T | 1 | - | - | - |
| S P R | 1 | O P Q R T | 2 | - | - | - |
| T O Q R S | 2 | O Q R S | 2 | - | - | - |

| | 2NN | 2d. | 4NN | 4d. | lrd_2 | lrd_4 |
|-----------|-----|-------------|-----|---------------------|-----------------------------|-----------------------------|
| A B C | 1 | B C D E | 6 | - | - | - |
| B A D | 1 | A C D E | 5 | - | $4/(6 + 5 + 4 + 5)$ | $4/(6 + 5 + 4 + 5)$ |
| C A D | 1 | A B D E | 5 | - | $4/(6 + 5 + 4 + 5)$ | $4/(6 + 5 + 4 + 5)$ |
| D B C | 1 | A B C E | 4 | $2/(1 + 1)$ | $4/(6 + 5 + 5 + 5)$ | $5/(5 + 5 + 4 + 4 + 5)$ |
| E D F | 4 | B C D F G | 5 | $2/(4 + 4)$ | $4/(2 + 2 + 3 + 3)$ | $4/(3 + 2 + 3 + 2)$ |
| F G H | 2 | G H I J | 3 | $2/(1 + 2)$ | $4/(3 + 2 + 3 + 2)$ | $4/(3 + 2 + 2 + 2)$ |
| G F H | 1 | F H I J | 2 | - | $4/(2 + 2 + 3 + 3)$ | $4/(2 + 2 + 2 + 2)$ |
| H G I J | 1 | F G I J | 2 | $3/(1 + 2 + 2)$ | $4/(2 + 2 + 3 + 4)$ | $5/(4 + 3 + 4 + 2 + 5)$ |
| I G H J | 2 | F G H J | 3 | - | $6/(4 + 3 + 5 + 4 + 5 + 5)$ | $6/(4 + 3 + 5 + 4 + 5 + 5)$ |
| J G H I K | 2 | G H I K | 2 | $4/(2 + 1 + 2 + 3)$ | $4/(2 + 1 + 2 + 2)$ | $4/(2 + 1 + 2 + 2)$ |
| K H J | 3 | G H I J L | 4 | $2/(2 + 3)$ | $4/(2 + 2 + 2 + 2)$ | $5/(4 + 3 + 4 + 2 + 5)$ |
| L K M O | 4 | K M N O P R | 5 | - | $4/(2 + 2 + 1 + 2)$ | $4/(2 + 2 + 2 + 1)$ |
| M N O P R | 2 | N O P R | 2 | $2/(1 + 1)$ | $4/(2 + 1 + 2 + 2)$ | $4/(2 + 1 + 2 + 2)$ |
| N O Q | 1 | M O P Q R | 2 | $2/(1 + 1)$ | - | - |
| O M N P R | 1 | M N P R | 1 | $4/(2 + 1 + 1 + 1)$ | $4/(2 + 2 + 2 + 1)$ | $4/(2 + 2 + 2 + 1)$ |
| P O S | 1 | M N O R S | 2 | - | - | - |
| Q N R | 1 | N O R S T | 2 | - | - | - |
| R O Q S T | 1 | O Q S T | 1 | - | - | - |
| S P R | 1 | O P Q R T | 2 | - | - | - |
| T O Q R S | 2 | O Q R S | 2 | - | - | - |

| | 2NN | 2d. | 4NN | 4d. | lrd_2 | lrd_4 |
|-----------|-----|-------------|-----|---------------------|-----------------------------|-------------------------|
| A B C | 1 | B C D E | 6 | - | - | - |
| B A D | 1 | A C D E | 5 | - | $4/(6 + 5 + 4 + 5)$ | $4/(6 + 5 + 4 + 5)$ |
| C A D | 1 | A B D E | 5 | - | $4/(6 + 5 + 4 + 5)$ | $4/(6 + 5 + 4 + 5)$ |
| D B C | 1 | A B C E | 4 | $2/(1 + 1)$ | $4/(6 + 5 + 5 + 5)$ | $5/(5 + 5 + 4 + 4 + 5)$ |
| E D F | 4 | B C D F G | 5 | $2/(4 + 4)$ | $4/(2 + 2 + 3 + 3)$ | $4/(3 + 2 + 3 + 2)$ |
| F G H | 2 | G H I J | 3 | $2/(1 + 2)$ | $4/(3 + 2 + 3 + 2)$ | $4/(3 + 2 + 2 + 2)$ |
| G F H | 1 | F H I J | 2 | - | $4/(2 + 2 + 3 + 3)$ | $4/(3 + 2 + 2 + 2)$ |
| H G I J | 1 | F G I J | 2 | $3/(1 + 2 + 2)$ | $4/(2 + 2 + 3 + 4)$ | $5/(4 + 3 + 4 + 2 + 5)$ |
| I G H J | 2 | F G H J | 3 | - | $6/(4 + 3 + 5 + 4 + 5 + 5)$ | $4/(2 + 2 + 2 + 2)$ |
| J G H I K | 2 | G H I K | 2 | $4/(2 + 1 + 2 + 3)$ | $4/(2 + 2 + 2 + 2)$ | $5/(2 + 1 + 2 + 2 + 2)$ |
| K H J | 3 | G H I J L | 4 | $2/(2 + 3)$ | $4/(2 + 2 + 2 + 1)$ | $4/(2 + 2 + 2 + 1)$ |
| L K M O | 4 | K M N O P R | 5 | - | $4/(2 + 2 + 2 + 1 + 1)$ | $4/(2 + 2 + 2 + 1)$ |
| M N O P R | 2 | N O P R | 2 | $4/(2 + 2 + 1 + 2)$ | $4/(2 + 1 + 2 + 2)$ | $5/(2 + 1 + 2 + 2 + 2)$ |
| N O Q | 1 | M O P Q R | 2 | $2/(1 + 1)$ | $4/(2 + 2 + 2 + 1)$ | $4/(2 + 2 + 2 + 1)$ |
| O M N P R | 1 | M N P R | 1 | $4/(2 + 1 + 1 + 1)$ | $4/(2 + 2 + 2 + 1)$ | $4/(2 + 2 + 2 + 1)$ |
| P O S | 1 | M N O R S | 2 | - | - | - |
| Q N R | 1 | N O R S T | 2 | - | - | - |
| R O Q S T | 1 | O Q S T | 1 | - | - | - |
| S P R | 1 | O P Q R T | 2 | - | - | - |
| T O Q R S | 2 | O Q R S | 2 | - | - | - |

| | 2NN | 2d. | 4NN | 4d. | lrd_2 | lrd_4 |
|-----------|-----|-------------|-----|---------------------|-----------------------------|-------------------------|
| A B C | 1 | B C D E | 6 | - | - | - |
| B A D | 1 | A C D E | 5 | - | $4/(6 + 5 + 4 + 5)$ | $4/(6 + 5 + 4 + 5)$ |
| C A D | 1 | A B D E | 5 | - | $4/(6 + 5 + 4 + 5)$ | $4/(6 + 5 + 4 + 5)$ |
| D B C | 1 | A B C E | 4 | $2/(1 + 1)$ | $4/(6 + 5 + 5 + 5)$ | $5/(5 + 5 + 4 + 4 + 5)$ |
| E D F | 4 | B C D F G | 5 | $2/(4 + 4)$ | $4/(2 + 2 + 3 + 3)$ | $4/(3 + 2 + 3 + 2)$ |
| F G H | 2 | G H I J | 3 | $2/(1 + 2)$ | $4/(3 + 2 + 3 + 2)$ | $4/(3 + 2 + 2 + 2)$ |
| G F H | 1 | F H I J | 2 | - | $4/(2 + 2 + 3 + 3)$ | $4/(3 + 2 + 2 + 2)$ |
| H G I J | 1 | F G I J | 2 | $3/(1 + 2 + 2)$ | $4/(2 + 2 + 3 + 4)$ | $5/(4 + 3 + 4 + 2 + 5)$ |
| I G H J | 2 | F G H J | 3 | - | $6/(4 + 3 + 5 + 4 + 5 + 5)$ | $4/(2 + 2 + 2 + 2)$ |
| J G H I K | 2 | G H I K | 2 | $4/(2 + 1 + 2 + 3)$ | $4/(2 + 2 + 2 + 2)$ | $5/(2 + 1 + 2 + 2 + 2)$ |
| K H J | 3 | G H I J L | 4 | $2/(2 + 3)$ | $4/(2 + 2 + 2 + 1)$ | $4/(2 + 2 + 2 + 1)$ |
| L K M O | 4 | K M N O P R | 5 | - | $4/(2 + 2 + 2 + 1 + 1)$ | $4/(2 + 2 + 2 + 1)$ |
| M N O P R | 2 | N O P R | 2 | $2/(1 + 1)$ | $4/(2 + 1 + 1 + 1)$ | $4/(2 + 1 + 1 + 1)$ |
| N O Q | 1 | M O P Q R | 2 | $2/(1 + 1)$ | $5/(2 + 1 + 2 + 2 + 2)$ | $5/(2 + 1 + 2 + 2 + 2)$ |
| O M N P R | 1 | M N P R | 1 | $4/(2 + 1 + 1 + 1)$ | $4/(2 + 2 + 2 + 1)$ | $4/(2 + 2 + 2 + 1)$ |
| P O S | 1 | M N O R S | 2 | $2/(1 + 1)$ | - | - |
| Q N R | 1 | N O R S T | 2 | - | - | - |
| R O Q S T | 1 | O Q S T | 1 | - | - | - |
| S P R | 1 | O P Q R T | 2 | - | - | - |
| T O Q R S | 2 | O Q R S | 2 | - | - | - |

| | 2NN | 2d. | 4NN | 4d. | lrd_2 | lrd_4 |
|-----------|-----|-------------|-----|-------------------------|-----------------------------|-----------------------------|
| A B C | 1 | B C D E | 6 | - | - | - |
| B A D | 1 | A C D E | 5 | - | $4/(6 + 5 + 4 + 5)$ | $4/(6 + 5 + 4 + 5)$ |
| C A D | 1 | A B D E | 5 | - | $4/(6 + 5 + 4 + 5)$ | $4/(6 + 5 + 4 + 5)$ |
| D B C | 1 | A B C E | 4 | $2/(1 + 1)$ | $4/(6 + 5 + 5 + 5)$ | $5/(5 + 5 + 4 + 4 + 5)$ |
| E D F | 4 | B C D F G | 5 | $2/(4 + 4)$ | $4/(2 + 2 + 3 + 3)$ | $4/(3 + 2 + 3 + 2)$ |
| F G H | 2 | G H I J | 3 | $2/(1 + 2)$ | $4/(3 + 2 + 3 + 2)$ | $4/(3 + 2 + 2 + 2)$ |
| G F H | 1 | F H I J | 2 | - | $4/(2 + 2 + 3 + 3)$ | $4/(2 + 2 + 2 + 2)$ |
| H G I J | 1 | F G I J | 2 | $3/(1 + 2 + 2)$ | $4/(2 + 2 + 3 + 4)$ | $5/(4 + 3 + 4 + 2 + 5)$ |
| I G H J | 2 | F G H J | 3 | - | $6/(4 + 3 + 5 + 4 + 5 + 5)$ | $4/(2 + 1 + 2 + 2)$ |
| J G H I K | 2 | G H I K | 2 | $4/(2 + 1 + 2 + 3)$ | $5/(2 + 1 + 2 + 2 + 2)$ | $4/(2 + 2 + 2 + 1)$ |
| K H J | 3 | G H I J L | 4 | $2/(2 + 3)$ | $5/(2 + 2 + 1 + 2 + 2)$ | $5/(2 + 2 + 1 + 2 + 2)$ |
| L K M O | 4 | K M N O P R | 5 | - | $5/(2 + 2 + 1 + 2 + 2 + 2)$ | $4/(2 + 2 + 1 + 2 + 2)$ |
| M N O P R | 2 | N O P R | 2 | $4/(2 + 2 + 1 + 2)$ | $4/(2 + 2 + 1 + 2 + 2)$ | $4/(2 + 2 + 1 + 2 + 2)$ |
| N O Q | 1 | M O P Q R | 2 | $2/(1 + 1)$ | $5/(2 + 2 + 1 + 2 + 2 + 2)$ | $4/(2 + 2 + 2 + 1)$ |
| O M N P R | 1 | M N P R | 1 | $4/(2 + 1 + 1 + 1 + 1)$ | $5/(2 + 2 + 1 + 2 + 2 + 2)$ | $5/(2 + 2 + 1 + 2 + 2 + 2)$ |
| P O S | 1 | M N O R S | 2 | $2/(1 + 1)$ | - | - |
| Q N R | 1 | N O R S T | 2 | - | - | - |
| R O Q S T | 1 | O Q S T | 1 | - | - | - |
| S P R | 1 | O P Q R T | 2 | - | - | - |
| T O Q R S | 2 | O Q R S | 2 | - | - | - |

| | 2NN | 2d. | 4NN | 4d. | lrd_2 | lrd_4 |
|-----------|-----|-------------|-----|---------------------|-------------------------|-----------------------------|
| A B C | 1 | B C D E | 6 | - | - | - |
| B A D | 1 | A C D E | 5 | - | $4/(6 + 5 + 4 + 5)$ | $4/(6 + 5 + 4 + 5)$ |
| C A D | 1 | A B D E | 5 | - | $4/(6 + 5 + 4 + 5)$ | $4/(6 + 5 + 4 + 5)$ |
| D B C | 1 | A B C E | 4 | $2/(1 + 1)$ | $4/(6 + 5 + 5 + 5)$ | $5/(5 + 5 + 4 + 4 + 5)$ |
| E D F | 4 | B C D F G | 5 | $2/(4 + 4)$ | $4/(2 + 2 + 3 + 3)$ | $4/(3 + 2 + 3 + 2)$ |
| F G H | 2 | G H I J | 3 | $2/(1 + 2)$ | $4/(3 + 2 + 3 + 2)$ | $4/(3 + 2 + 2 + 2)$ |
| G F H | 1 | F H I J | 2 | - | $4/(2 + 2 + 3 + 3)$ | $4/(3 + 2 + 2 + 2)$ |
| H G I J | 1 | F G I J | 2 | $3/(1 + 2 + 2)$ | $4/(2 + 2 + 3 + 4)$ | $5/(4 + 3 + 4 + 2 + 5)$ |
| I G H J | 2 | F G H J | 3 | - | $4/(2 + 2 + 2 + 2)$ | $6/(4 + 3 + 5 + 4 + 5 + 5)$ |
| J G H I K | 2 | G H I K | 2 | $4/(2 + 1 + 2 + 3)$ | $4/(2 + 1 + 2 + 2)$ | $5/(2 + 1 + 2 + 2 + 2)$ |
| K H J | 3 | G H I J L | 4 | $2/(2 + 3)$ | $4/(2 + 2 + 2 + 1)$ | $5/(2 + 2 + 1 + 2 + 1)$ |
| L K M O R | 4 | K M N O P R | 5 | - | $5/(2 + 2 + 1 + 2 + 1)$ | $5/(2 + 2 + 1 + 2 + 1)$ |
| M N O P R | 2 | N O P R | 2 | $4/(2 + 2 + 1 + 2)$ | $4/(2 + 2 + 1 + 2 + 1)$ | $6/(4 + 3 + 5 + 4 + 5 + 5)$ |
| N O Q | 1 | M O P Q R | 2 | $2/(1 + 1)$ | $4/(2 + 2 + 2 + 1)$ | $4/(2 + 2 + 2 + 2 + 2)$ |
| O M N P R | 1 | M N P R | 1 | $4/(2 + 1 + 1 + 1)$ | $4/(2 + 2 + 1 + 2)$ | $5/(2 + 1 + 2 + 2 + 2)$ |
| P O S | 1 | M N O R S | 2 | $2/(1 + 1)$ | $5/(2 + 2 + 1 + 2 + 2)$ | $5/(2 + 2 + 1 + 2 + 2)$ |
| Q N R | 1 | N O R S T | 2 | - | - | - |
| R O Q S T | 1 | O Q S T | 1 | $4/(1 + 1 + 1 + 2)$ | - | - |
| S P R | 1 | O P Q R T | 2 | - | - | - |
| T O Q R S | 2 | O Q R S | 2 | - | - | - |

| | 2NN | 2d. | 4NN | 4d. | lrd_2 | lrd_4 |
|-----------|-----|-------------|-----|---------------------|-----------------------------|-------------------------|
| A B C | 1 | B C D E | 6 | - | - | - |
| B A D | 1 | A C D E | 5 | - | $4/(6 + 5 + 4 + 5)$ | $4/(6 + 5 + 4 + 5)$ |
| C A D | 1 | A B D E | 5 | - | $4/(6 + 5 + 4 + 5)$ | $4/(6 + 5 + 4 + 5)$ |
| D B C | 1 | A B C E | 4 | $2/(1 + 1)$ | $4/(6 + 5 + 5 + 5)$ | $5/(5 + 5 + 4 + 4 + 5)$ |
| E D F | 4 | B C D F G | 5 | $2/(4 + 4)$ | $4/(2 + 2 + 3 + 3)$ | $4/(3 + 2 + 3 + 2)$ |
| F G H | 2 | G H I J | 3 | $2/(1 + 2)$ | $4/(3 + 2 + 3 + 2)$ | $4/(3 + 2 + 2 + 2)$ |
| G F H | 1 | F H I J | 2 | - | $4/(2 + 2 + 3 + 3)$ | $4/(2 + 2 + 2 + 2)$ |
| H G I J | 1 | F G I J | 2 | $3/(1 + 2 + 2)$ | $4/(2 + 2 + 3 + 4)$ | $5/(4 + 3 + 4 + 2 + 5)$ |
| I G H J | 2 | F G H J | 3 | - | $6/(4 + 3 + 5 + 4 + 5 + 5)$ | $4/(2 + 2 + 2 + 2)$ |
| J G H I K | 2 | G H I K | 2 | $4/(2 + 1 + 2 + 3)$ | $4/(2 + 2 + 2 + 2)$ | $5/(2 + 1 + 2 + 2 + 2)$ |
| K H J | 3 | G H I J L | 4 | $2/(2 + 3)$ | $4/(2 + 2 + 2 + 1)$ | $4/(2 + 2 + 1 + 2)$ |
| L K M O | 4 | K M N O P R | 5 | - | $4/(2 + 2 + 1 + 2)$ | $4/(2 + 2 + 1 + 2)$ |
| M N O P R | 2 | N O P R | 2 | $2/(1 + 1)$ | $5/(2 + 1 + 2 + 2 + 2)$ | $5/(2 + 1 + 2 + 2 + 2)$ |
| N O Q | 1 | M O P Q R | 2 | $2/(1 + 1)$ | $4/(2 + 2 + 2 + 1)$ | $4/(2 + 2 + 1 + 2)$ |
| O M N P R | 1 | M N P R | 1 | $4/(2 + 1 + 1 + 1)$ | $5/(2 + 2 + 1 + 2 + 2)$ | $4/(1 + 2 + 2 + 2 + 2)$ |
| P O S | 1 | M N O R S | 2 | $2/(1 + 1)$ | - | - |
| Q N R | 1 | N O R S T | 2 | - | - | - |
| R O Q S T | 1 | O Q S T | 1 | $4/(1 + 1 + 1 + 2)$ | - | - |
| S P R | 1 | O P Q R T | 2 | - | - | - |
| T O Q R S | 2 | O Q R S | 2 | - | - | - |

Finale LOF-Werte für $k = 2$:

$$LOF_2(E) := \frac{\frac{2}{2} + \frac{2}{3}}{2} / \frac{2}{8}$$
$$\approx 3.333$$

$$LOF_2(O) := \frac{\frac{4}{7} + \frac{2}{2} + \frac{2}{2} + \frac{4}{5}}{4} / \frac{4}{5}$$
$$\approx 1.054$$

$$LOF_2(K) := \frac{\frac{3}{5} + \frac{4}{8}}{2} / \frac{2}{5}$$
$$\approx 1.375$$

Finale LOF-Werte für $k = 4$:

$$LOF_4(E) := \frac{\frac{4}{20} + \frac{4}{20} + \frac{4}{21} + \frac{4}{10} + \frac{4}{10}}{5} / \frac{5}{23} \\ \approx 1.279$$

$$LOF_4(O) := \frac{\frac{4}{7} + \frac{5}{9} + \frac{5}{9} + \frac{4}{7}}{4} / \frac{4}{7} \\ \approx 0.986$$

$$LOF_4(K) := \frac{\frac{4}{10} + \frac{4}{10} + \frac{4}{9} + \frac{4}{11} + \frac{6}{26}}{5} / \frac{5}{18} \\ \approx 1.324$$

Finale LOF-Werte für $k = 4$:

$$LOF_4(E) := \frac{\frac{4}{20} + \frac{4}{20} + \frac{4}{21} + \frac{4}{10} + \frac{4}{10}}{5} / \frac{5}{23} \\ \approx 1.279$$

$$LOF_4(O) := \frac{\frac{4}{7} + \frac{5}{9} + \frac{5}{9} + \frac{4}{7}}{4} / \frac{4}{7} \\ \approx 0.986$$

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$|\mathcal{N}(p)|$ des betrachteten Objektes

$|\mathcal{N}(o)|$ der Nachbarn

Summe der Erreichbarkeit von o / p

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Outlier
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Aufgabe 9-2

Sowohl LOF als auch k NN haben bei $k = 4 = |\{A, B, C, D\}|$ das Problem, dass $k + 1$ größer ist als der kleinste Cluster.

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Aber: für 4NN wird der Punkt A der größte Ausreißer.

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Bei LOF, wird lediglich E weniger deutlich, da sich die Dichten der Nachbarn B, C und D reduzieren.

Aber es hat immernoch einen der größten Werte, und A, B, C, D bleiben “Inlier”!

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⇒ LOF bleibt auch bei ungünstigem k zuverlässiger.