Overview

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   B) Solution

III. Conclusion
   F) Conclusion

II. Survey & Mathematical results
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   D) Neural networks
   E) Logistic regression
   F) Discriminant analysis
   G) Answer Tree
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Problem: Odour from canalization

Odour can not be assigned to a special substance

Responsible for odour:

- oxygen
- nitrate
- organic material
- sulphur and sulphur chemical compounds

The human nose doesn`t smell only one substance.

The odour in canalization depends on a lot of factors:

- temperature
- raining water
- industrial water
- quantity of organic material
- velocity of water

In most cases we can only measure the situation at a time point, but not for a longer time period.
Problem: Avoiding odour

Avoiding odour

- oxygen, $O_2$

Disadvantage: High fire danger

- hydrogene peroxide $H_2O_2$

Disadvantage: acidly

- Calciumnitrat [NUTRIOXÂ®]

Disadvantage: adorable

Costs: NUTRIOXÂ® is sucessfull. The costs are 0.3 € / m³ water

- Mask of odour etc.

for avoiding odour we have to determine the odour quantity
Olfactometric measurement

Disadvantage:
• High costs
• Only a measurement for one time point

Unit
The odour unit is defined at the barrier of the concentration of the sniffable material
1 Odour unit (OU/m³) (DIN EN 13725 / VDI - RICHTLINIE 3881)
The test person informs us about the lowest concentration he can smell.

Difficulty:
• Differences between test persons
• Adequacy of test persons

Olfactometry: objective measurement of odour

clean air

olfactometer

sample
There are three different kinds of sensor measurement:

- oscillating crystals
- electrical resistance
- optical measurement

for an unspecific measurement all methods are comparable with each other.

(for application in a big city (more than 1,5 Mio inhabitants) we decide to take the electrical resistance.

The electronic nose consists on many sensors.

The signals has to be interpreted for odour.

**Necessary: An assignment** \( f (\text{sensor signals}) = \text{odour quantity} \)

**We need a suitable mathematical procedure**
The continuous measurement of the electronic nose has to be assigned to an olfactrometric measurement*

Together with the company for canalization we have to find a barrier for a critical value of odour quantity

500 OU/m³

* After 5 hours there could be a difference between the olfactometric measurements and sensor signals

** We have no measurement with an exact value of 500 OU/m³
Neural networks

Irrelevant: Statement about one sensor

Relevant: Interaction between sensors

\[ P(\text{barrier} > x | \text{Sensorsignals}) = p \]

Under the conditions of sensorsignals we get a probability

Further more: Non-linearity of concentrations
Neural networks Algorithm

**Step 1.**
\[ E = \sum_{k=1}^{N} (\tilde{y}_k - y_k)^2 \]

**Differences between estimation and reality**

**Aim: Minimum of error E**

**Step 2.**
\[ z_j = g\left(\sum_{i=1}^{n} w_i \cdot x_i\right) \]

Hidden layer (Sigmoid-function)

**Step 3.**
\[ a = h\left(\sum_{j=1}^{m} u_j \cdot z_j\right) \]

Output layer (Sigmoid-function)

**Step 4.**
\[ \tilde{y} = F(a) \]

Function for output (Interpretation)

**Step 5.**
\[ w_i^\text{new} = w_i^\text{old} + \alpha \cdot \Delta w_i \]

Initialisation of raise in hidden layer

**Step 6.**
\[ u_j = u_j^\text{old} \]

Initialisation of raise in output layer

At start: random weights
Application of Logistic regression

Irrelevant: Interaction of sensors

Relevant: assignment

Similar to one-layer neural network

\[ P(\text{barrier} > x | \text{barrier}) = p \]
Application of Discriminant analysis

Irrelevant: No results for interaction between sensors

Relevant: statement for the assignment to a category

\[ f(\text{Sensorsignals}) = y \]

- \( y > \text{critical value} \) \( \rightarrow \) odour quantity = "1"
- \( y < \text{critical value} \) \( \rightarrow \) odour quantity = "0"

Only linear separation
Application of Answer Tree

Irrelevant: multivariate

Relevant: Finding a decision tree

Example:
Cut-off for target and sensor signals

Most relevant Sensor „5“ = 0 and next relevant Sensor „4“ = 1 → odour quantity „1“ with a probability 75 %

Easy to handle for the engineers

Either you determine the cut off-value (CHAID) or it could be determined by the procedure (CRT)
Results for Explanation
(n₁=57 measurements)

*Explanation: Using the known data

<table>
<thead>
<tr>
<th>Method</th>
<th>&lt;500 OE(m³)</th>
<th>&gt;500 OE/m³</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Neural network</td>
<td>11 (64.7 %)</td>
<td>35 (87.5 %)</td>
<td>46 (80.7 %)</td>
</tr>
<tr>
<td>Logistic regression</td>
<td>11 (64.7 %)</td>
<td>35 (87.5 %)</td>
<td>46 (80.7 %)</td>
</tr>
<tr>
<td>Discriminant analysis</td>
<td>13 (76.4 %)</td>
<td>27 (67.5 %)</td>
<td>40 (70.2 %)</td>
</tr>
<tr>
<td>Answer Tree</td>
<td>0 (0 %)</td>
<td>40 (100 %)</td>
<td>40 (70.2 %)</td>
</tr>
</tbody>
</table>
Explanation
(n₁ = 57 measurements)

- Explanation in one part of the sample (ca. 50%)

**odour quantity in categories**

<table>
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<tr>
<td>Discriminant analysis</td>
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<tr>
<td>Logistic regression</td>
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<tr>
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*Explanation in one part of the sample (ca. 50%)*
## Prediction
(n = 58 measurements)

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<th>&lt;500 OE (m³)</th>
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<th>Total</th>
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</thead>
<tbody>
<tr>
<td>Neural networks</td>
<td>17 (68%)</td>
<td>30 (90.8%)</td>
<td>47 (81%)</td>
</tr>
<tr>
<td>Logistic regression</td>
<td>13 (52%)</td>
<td>26 (78.8%)</td>
<td>39 (67.2%)</td>
</tr>
<tr>
<td>Discriminance analysis</td>
<td>18 (72%)</td>
<td>24 (72.7%)</td>
<td>40 (70.2%)</td>
</tr>
<tr>
<td>Answer Tree</td>
<td>0 (0%)</td>
<td>40 (100%)</td>
<td>40 (70.2%)</td>
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</tbody>
</table>

*Prediction on unknown data: Validation*
Prediction (n₂=58 measurements)

odour quantity in categories:

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<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Answer Tree</td>
<td>100%</td>
<td>0%</td>
<td>100%</td>
</tr>
<tr>
<td>Discriminancne</td>
<td>100%</td>
<td>0%</td>
<td>100%</td>
</tr>
<tr>
<td>Logistic regression</td>
<td>100%</td>
<td>0%</td>
<td>100%</td>
</tr>
<tr>
<td>Neural network</td>
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Prediction on unknown data: Validation
Shape Analysis for odour quality

Explosive materials

Diagramm: Explosive materials

- hexogen
- black powder
- nitrocellulose
- smoke residue
- triaceton peroxide
Conclusion

- All procedures are useful for estimating the odour quantity.
- For Answer Tree you have only a reduced number of sensors.
- Shape Analysis is useful for odour quality.
Forecast

- More measurements
- Improvement of measurements (on time olfactometric measurements)
- Odour Profiles for every substance and mixture of substances
Electronic Noses with Neural Networks for Odour Quality and Quantity

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