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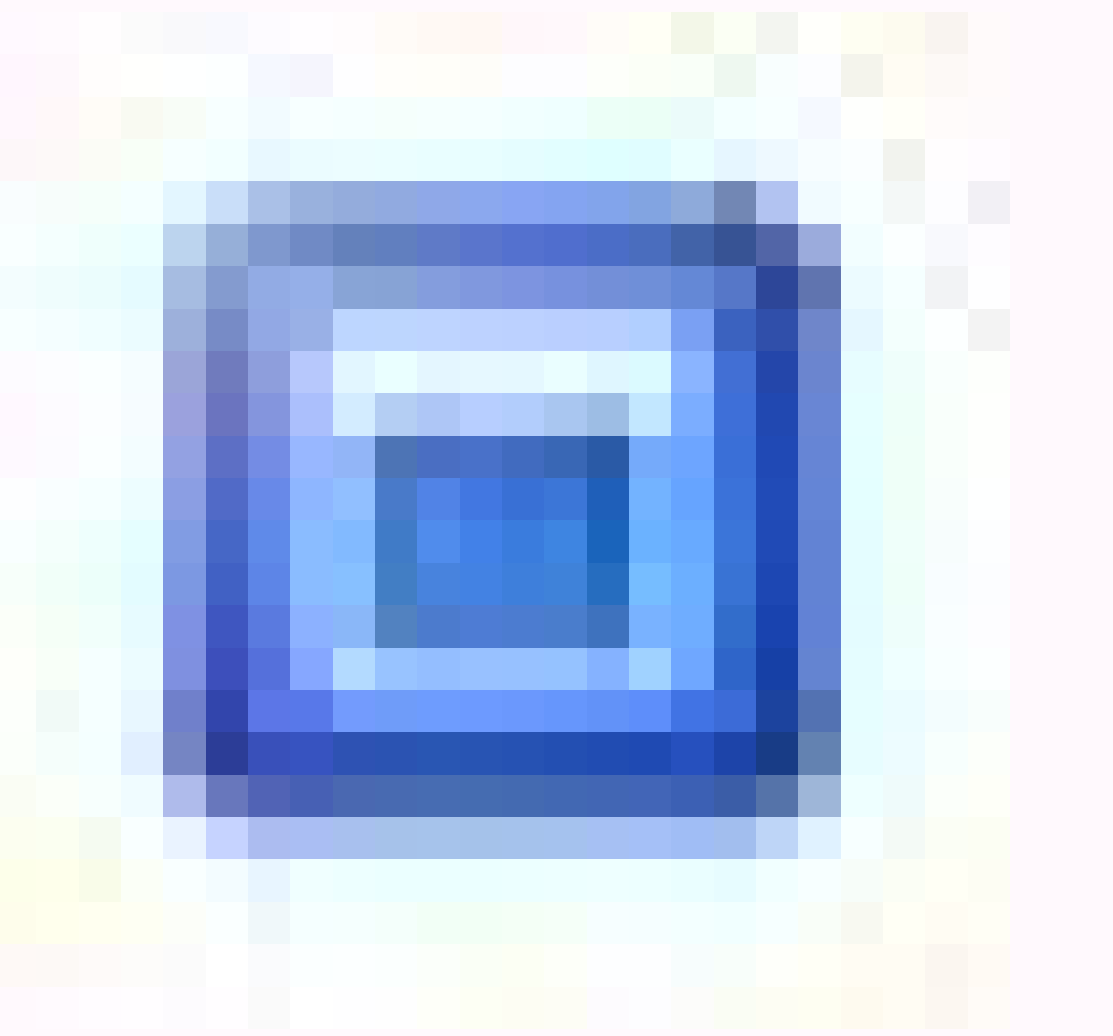
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## Examples

Sub-Sections:  
**Probabilistic Reasoning**: example of reasoning with MaxEnt compared with classical (monotonic) reasoning.  
**Properties**: examples concerning context sensitivity and missing truthfunctionality in probability theory.  
**Cost Matrix**: an example for translating probabilities into decisions (as used and described in the PIT-application LEXMED).

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**Probabilistic Reasoning**  
Probabilities deliver a well-researched method of reasoning with uncertain knowledge. They form a unified language to express knowledge, which may be inductively generated from data or as well result from experts or literature. Using probabilities means expressing the given knowledge in the form of probabilistic statements or 'rules'. Of course, the user is more interested in some conclusions, based on this knowledge. A first attempt might be to use the wellknown concepts of monotonic reasoning for conclusions, where the term *monotonic* describes, that all the conclusion will remain valid given additional knowledge (rules).  
**Probabilistic Reasoning I (monotonic)**  
In this type of logic, the conclusions should be true, whenever the premises (i.e. the given knowledge) are true. We give an example of this type of probabilistic reasoning:

We may have specified the following database DB of rules :  
About 70% of balls in an urn U have red spots.  
About 80% of balls in an urn U have green spots. Additionally we might have the following query, based on the knowledge in DB:  
How many balls in urn U could we expect to have red and green spots ?  
Now it is easy to calculate, that there is a minimum of 50% (as the overlap is 70% + 80% - 100 % = 50 %) and a maximum of 70 % (if all balls with red spots do show green spots) of balls with spots in two colours. So our answer is  
We could expect between 50% and 70% of balls with red and green spots.  
This answer is correct and it will stay correct even under additional knowledge. But this answer is not useful in the general case. Imagine a few more premises and slightly more complex queries and believe, that we will end up with results like  
We could expect between 0% and 100% of balls with property x, y and z.  
which of course is a fact by definition and not worth mentioning.  
**Probabilistic Reasoning: II (non-monotonic)**  
Therefore we are not satisfied by monotonic reasoning and prefer a different type of logic. In this logic, our conclusions will not be true in all cases, where the premises are true. They will be true only in MOST cases. (For a more precise meaning see the publications).  
Therefore we will receive a non-monotonic behavior: Given additional knowledge, we might change our opinion. (The most classical example is that knowing of an object to be a bird, you will conclude: it flies, receiving the additional knowledge that the object looks like a penguin, you will conclude: It does not fly.) To sketch the idea for the example of above, lets first look at the following table:

| In Symbols                             | P-Model 1 | P-Model 2 | P-Model 3 |
|----------------------------------------|-----------|-----------|-----------|
| P(balls = red sp. and green sp.)       | 0.5       | 0.56      | 0.7       |
| P(balls = red sp. and no green sp.)    | 0.2       | 0.14      | 0.0       |
| P(balls = no red sp. and green sp.)    | 0.3       | 0.24      | 0.1       |
| P(balls = no red sp. and no green sp.) | 0.0       | 0.06      | 0.2       |

The first column lists the set of our 4 elementary events (in brackets). A **probability measure** relates positive numbers to this events, which sum up to one. Therefore, the columns named P-Model describe (together with the column symbols) some probability measures on our set of events. The columns are names P-Model (for probability model), as these probability measures additionally fulfill our premises: in every column we have 70 % of balls with red spots and 80 % of balls with green spots. In fact, there are infinitely many P-Models, which fulfill our premises (resp. rules, resp. constraints). The **method of Maximum Entropy** now says:  
• Measure the (information theoretic resp. shannon-) entropy of the probability model.  
• Choose the P-model with maximal entropy  
(in our form of constraints it is theoretically guaranteed, that there is exactly one model with that property, given the constraints are consistent.)

Its main argument is, that assuming a discrete number of balls in the urn, the P-Models are not distributed uniformly. Moreover they are 'concentrated around' the P-Model with highest entropy (for the precise meaning of 'concentrated around' this see any corresponding textbooks). Therefore the P-Model with highest entropy is the best choice we could make, if we are forced to make a decision.  
In our example it is not difficult to measure the entropy: For every column we have to perform  $\text{Sum}((-x_i) \cdot \ln(x_i))$  (where the base of the logarithm is not important for the process). We receive  
for the column P-Model 1  $0.173 + 0.322 + 0.361 + 0 = 0.856$   
for the column P-Model 2  $0.320 + 0.275 + 0.343 + 0.169 = 1.112$   
for the column P-Model 3  $0.250 + 0.0 + 0.230 + 0.322 = 0.802$ .  
If we have to decide between these three probability models, the method of maximum entropy would choose the P-Model 2. Furthermore, the P-Model 2 is also the maximum entropy model of all (infinite many) P-Models of our two rules and therefore reveals one of the property of the method: As this P-model is (given the constraints of above) simply calculated by the assumption of independence, (e.g.  $0.56 = 0.7 \cdot 0.8$ ) the choice of maximum entropy is somehow correlated to the use of independence assumptions. For further details we refer to the publications.

**Problems of the implementations**  
Now it should be clear, that beside some deductive elements in our approach (the infinite set of probability models fulfilling the constraints), we mainly use an inductive logic (using the principle of maximum entropy to choose the model with minimal information from the infinite set of probability models). The problem of an implementation of this approach is not to find the maximum entropy model in an infinite set (as it could be calculated) but to keep the size of representation small. Adding a two valued variable e.g. doubles the number of elementary events which have to be distinguished (i.e. we have exponential complexity in relation to the number of variables).  
To solve this problem for our applications, we use properties of Maximum Entropy to simplify the representation of the problem (without changing the result) already at the beginning of our calculations (see the use of the **Principle of Independence** and the use of the **Principle of Indifference** in our publications).

## Examples of Context Sensitivity of Probability Theory

**Example 1**  
The aim of example 1 is to demonstrate, that we may have different pieces of information about the same proposition (piece of knowledge) in different contexts. We demonstrate this by the following example where we prove, that a given probability information (C1), about a proposition c in context a, does not imply anything about the possible values q1 and q2 in the statements (Q1) and (Q2) about c in the extended contexts 'a and b' resp. 'a or b'.

(C1) If I know a (and only a), then the probability of c is p1 in (0,1).  
-----  
(Q1) If I know a and b, what is the probability q1 of c ?  
(Q2) If I know a or b, what is the probability q2 of c ?

Formally:  
Using '∧' for 'and' and '∨' for 'or'  
and '→' for the conditional - i.e. P(a → b) is another notation for P(b | a) (= P(a ∩ b) / P(a)) - we get:  
(C1) P(a → c) = p1;  
-----  
(Q1) P(a ∩ b → c) = q1;  
(Q2) P(a ∪ b → c) = q2;

In the following table the columns P-Model 1 and P-Model 2 describe two probability measures which both fulfill the constraint (C1). (In our notation, we use '∧' for 'not' and '∨' for a small positive number close to 0 (epsilon) which, in particular, is chosen smaller than p1). The rows of the table correspond to the 8 elementary events a'∩b'c,...,a'∩b'c', whose probabilities are given in the table either referred to as P(elementary event) in column 1 or by the probability vector (v1,...,v8) on column 2

| El-Event        | El-Variable | Values in P-Model 1 | Values in P-Model 2 |
|-----------------|-------------|---------------------|---------------------|
| P(a ∩ b ∩ c)    | v1          | 0                   | e*p1/(1-p1)         |
| P(a ∩ b ∩ c')   | v2          | e*(1-p1)p1          | 0                   |
| P(a ∩ b' ∩ c)   | v3          | e*p1p1              | 0                   |
| P(a ∩ b' ∩ c')  | v4          | 0                   | e*(1-p1)(1-p1)      |
| P(a' ∩ b ∩ c)   | v5          | 0                   | (1-p1-e)/(1-p1)     |
| P(a' ∩ b ∩ c')  | v6          | (p1-e)p1            | 0                   |
| P(a' ∩ b' ∩ c)  | v7          | 0                   | 0                   |
| P(a' ∩ b' ∩ c') | v8          | 0                   | 0                   |

**P-Model 1 and P-Model 2 are P-models:**  
We have to show that all v1,...,v8 are nonnegative and (v1 + v2 + ... + v8) = 1.  
This holds because  
p1 is in the interval (0,1) and  
(e\*(1-p1) + e\*p1 + (p1-e)p1) = 1 resp. (e\*p1 + e\*(1-p1) + (1-p1-e)(1-p1) = 1.  
**Satisfying (C1):**  
With  
P(a) = v1+v2+v3+v4, P(a'∩c) = v1+v3, P(a'∩b) = v1+v2, P(a'∩b'∩c) = v1, P(a∩b) = v1+v2+v3+v4+v5+v6, P(a∩b'∩c) = v1+v3+v5  
we compute easily from (C1), (Q1) and (Q2) that  
p1 = (v1+v3) / (v1+v2+v3+v4)  
q1 = (v1) / (v1+v2)  
q2 = (v1+v3+v5) / (v1+v2+v3+v4+v5+v6)  
We now get that (C1) is fulfilled in  
• P-Model 1, because  
(v1+v3) / (v1+v2+v3+v4) = e\*p1 / (e\*(1-p1) + e\*p1) = p1 / ((1-p1) + p1) = p1  
• P-Model 2, because  
(v1+v3) / (v1+v2+v3+v4) = e\*p1 / (e\*p1 + e\*(1-p1)) = p1 / (p1 + (1-p1)) = p1  
**Computing q1:**  
In P-Model 1 holds: q1 = (v1) / (v1+v2) = 0/2 = 0  
In P-Model 2 holds: q1 = (v1) / (v1+v2) = v1 / (v1+0) = 1  
More generally we can say, since the constraint (C1) is convex, q1 can take every value in [0,1] independently of any value p1.  
**Computing q2:**  
In P-Model 1 holds: q2 = v3 / (v2+v3+v6) = e\*p1/p1 = e, i.e. arbitrarily close to 0.  
In P-Model 2 holds: q2 = (v1+v3+v5) / (v1+v2+v3+v4+v5+v6) = (v1+v5) / (v1+v4+v5)  
= (e\*p1 + 1-p1-e) / ((1-p1) + (e\*p1-1) + (1-p1)) / ((1-p1) + (1-e)), i.e. arbitrarily close to one.  
More generally we can say, since the constraint (C1) is convex, q2 can take every value in (0,1) independently of any value p1.

**Example 2**  
The aim of example 2 is to demonstrate, that we may have different information about the same variable in different contexts. We demonstrate this by proving, that even the combination of the constraints (C2) and (C3) does not restrict the possible values of the query (Q3) resp. it does not restrict it very much in case of query (Q4).

(C2) If I know a (and only a), then the probability of c is p2:  
-----  
(C3) If I know b (and only b), then the probability of c is p3:  
-----  
(Q3) If I know a and b, what is the probability q3 of c ?  
(Q4) If I know a or b, what is the probability q4 of c ?

Query (Q3) asks for the probability q3 of c given 'a and b' together with the probabilities p2 and p3, while query (Q4) asks for the probability q4 of c given 'a or b' together with the probabilities p2 and p3.  
Formally:  
(We use '∧' for 'not', '∧' for 'and' and '∨' for 'or' and the arrow in 'a → b' as conditional, equivalent to the notation '1 | a' where P(a → b) = P(a and b) / P(a) )

(C2) P(a → c) = p2;  
(C3) P(b → c) = p3;  
-----  
(Q3) P(a ∩ b → c) = q3;  
(Q4) P(a ∪ b → c) = q4;

The following table describes two probability models.

| El-Event        | El-Variable | Values in P-Model 3       | Values in P-Model 4       |
|-----------------|-------------|---------------------------|---------------------------|
| P(a ∩ b ∩ c)    | v1          | 0                         | p2*p3 / (p2+p3-p2*p3)     |
| P(a ∩ b ∩ c')   | v2          | (1-p2)*(1-p3) / (1-p2*p3) | 0                         |
| P(a ∩ b' ∩ c)   | v3          | p2*(1-p3) / (1-p2*p3)     | 0                         |
| P(a ∩ b' ∩ c')  | v4          | 0                         | (1-p2)*p3 / (p2+p3-p2*p3) |
| P(a' ∩ b ∩ c)   | v5          | p3*(1-p2) / (1-p2*p3)     | 0                         |
| P(a' ∩ b ∩ c')  | v6          | 0                         | (1-p3)*p2 / (p2+p3-p2*p3) |
| P(a' ∩ b' ∩ c)  | v7          | 0                         | 0                         |
| P(a' ∩ b' ∩ c') | v8          | 0                         | 0                         |

Recall that  
• {p2} is equivalent to (v1+v3) / (v1+v2+v3+v4)  
In P-Model 3 (C2) is fulfilled as  
(v1+v3) / (v1+v2+v3+v4) = p2(1-p3) / ((1-p2)\*(1-p3)+p2(1-p3)) = p2(1-p3) / ((1-p2)\*(1-p3)+p2(1-p3)) = p2 / (1-p2+p2) = p2  
In P-Model 4 (C2) is fulfilled as  
(v1+v3) / (v1+v2+v3+v4) = p2\*p3 / (p2\*p3 + (1-p2)\*p3) = p2  
• {p3} is equivalent to (v1+v5) / (v1+v2+v5+v6)  
In P-Model 3 (C3) is fulfilled as  
(v1+v5) / (v1+v2+v5+v6) = p3\*(1-p2) / ((1-p2)\*(1-p3)+p3\*(1-p2)) = p3(1-p2) / (1-p3-p2+p2\*p3 + p3(1-p2) + (1-p2) = p3  
In P-Model 4 (C3) is fulfilled as  
(v1+v5) / (v1+v2+v5+v6) = p2\*p3 / (p2\*p3 + (1-p3)\*p2) = p3  
• {q3} is equivalent to (v1) / (v1+v2)  
• {q4} is equivalent to (v1+v3+v5) / (v1+v2+v3+v4+v5+v6).



Concerning (Q3): Query (Q3) demonstrates, that we have complete freedom if we specialize the context, as q1 can take every value from [0,1] independently of any (fixed) value in (0,1) of p2 and p3.

Proof:  
We describe two probability models (i.e. these probability measures fulfil the constraints (C2) and (C3)).  
The column of P-Model 3 shows that q3 can take the value 0.  
The column of P-Model 4 shows that q3 can take the value 1.  
As the constraints (C2) and (C3) are convex and therefore any value inbetween two solutions can be taken, we have proved that q3 can take any value in [0,1]

#### Common Sense Example

This common sense example (from D. Dubois) models high values of q3 , given low values of p2 and p3.  
If you take a shower, you do not risk your life [0,0, 0.01]  
If you use a hairdryer, you do not risk your life [0,0, 0.01]  
If you take a shower and use a hairdryer (at the same time), you do risk your life. [0.9, 1.00]

Concerning (Q4):  
With query (Q4) we want to demonstrate, how extending the context means losing information, as the probability of (Q4) ranges over the following interval: [(p2\*p3 / (p2\*p3+p2\*p3)), (p2\*p3-2p2\*p3)/(1-p2\*p3)] , which we obtain if we use P-Model 4 to calculate the lower bound and P-Model 3 to calculate the upper bound. Again we recall that P-Model 3 and P-Model 4 fulfil the constraints (C2) and (C3).  
As the constraints (C2) and (C3) are convex and therefore any value between two solutions can occur, we proved that q4 can take any value in the described interval. Example: For p2 = p3 = 0.5 we receive for q4 the interval [1/3, 2/3].

#### Examples Concerning Truth Functionality

Example 3: The aim of example 3 is to demonstrate, that we can specify certain information for single statements, while still having additional freedom to specify different information for their combination. The classical definition of missing truth functionality is included in this case (see remark). In general terms, truth functionality is absent if there is no function, which allows to calculate the degree of belief of a compound sentence from the single sentences.

(C5) If I know a (and only a), then the probability of b is p5:  
(C6) If I know a (and only a), then the probability of c is p6:  
-----  
(Q5) If I know a (and only a), what is the probability q3 of (b and c) ?

Query (Q5) asks for the probability q3 of (b and c) given a and the probabilities p5 and p6.

Formally:  
(We use '∧' for 'not', '∧' for 'and' and '∨' for 'or'  
and the arrow in 'a → b' as conditional, equivalent to '1 | a' where 'P(a → b) = P(a and b) / P(a)' ); for  
(C5) P(a → b) = p5;  
(C6) P(a → c) = p6;  
-----  
(Q5) P(a → b∧c) = q5;

Remark:  
The classical concept of absent truth functionality is implied by the example above, as the statement  
'P(a∧b) is no function of P(a) and P(b)'  
can be reformulated as  
'P(∑True → a∧b) is no function of P(∑True → a) and P(∑True → b)'.  
This means that we consider the conditional probability as basic construct and the unconditional probability as special case of conditional probabilities.

The following table describes two probability models.

| El-Event       | El-Variable | Values in P-Model 5 | Values in P-Model 6 | Values in P-Model 7 |
|----------------|-------------|---------------------|---------------------|---------------------|
|                |             | (p5+p6 <= 1)        | (p5+p6> 1)          | -                   |
| P(a ∧ b ∧ c)   | v1          | 0                   | p5+p6-1             | min(p5,p6)          |
| P(a ∧ b ∧ ¬c)  | v2          | p5                  | 1-p6                | p5 - min(p5,p6)     |
| P(a ∧ ¬b ∧ c)  | v3          | p6                  | 1-p5                | p6 - min(p5,p6)     |
| P(a ∧ ¬b ∧ ¬c) | v4          | 1-p5-p6             | 0                   | 1- max(p5,p6)       |
| P(a ∧ b ∧ c)   | v5          | 0                   | 0                   | 0                   |
| P(a ∧ b ∧ ¬c)  | v6          | 0                   | 0                   | 0                   |
| P(a ∧ ¬b ∧ c)  | v7          | 0                   | 0                   | 0                   |
| P(a ∧ ¬b ∧ ¬c) | v8          | 0                   | 0                   | 0                   |

- Recall that
- (c5) is equivalent to (v1+v2) / (v1+v2+v3+v4)
  - (c6) is equivalent to (v1+v3) / (v1+v2+v3+v4)
  - (q5) is equivalent to (v1) / (v1+v2+v3+v4)

Concerning (Q5):  
The query (Q5) demonstrates, that the probability (q5) is not determined by the constraints (C5) and (C6).

We first show, that the lower bound of q5 is max(0,p5+p6-1).

Proof:  
Case p5+p6 <= 1.  
In P-Model 5, q5 = 0 / (0 + p5+p6+1-p5-p6) = 0.  
Case p5+p6 > 1.  
In P-Model 6, (p5+p6-1) / (p5+p6-1+(1-p5)+(1-p6)) = p5+p6-1.  
We therefore receive a lower bound of max(0,p5+p6-1) for q5. This value is minimal, as the overlap of the two sets is minimal, if the sets a and b only takes values in c if there is no other possibility.

We also show, that the upper bound for q5 is min(p5,p6).  
Proof:  
In P-Model 7 the upper bound for q5 is min(p5,p6). This value is the extreme case, as the overlap of b and c (in a) is maximal if (a and b) is in (a and c), (in which case we receive q5 = p5) or (a and a) is in (a and b) (with q5 = p6).

As the constraints are convex, q5 can take every value in the interval [max(0,p5+p6-1), min(p5,p6)] for fixed values p5 and p6 in [0,1].

#### Numerical Example for Query (Q5)

For p5=0.45 and p6=0.55 we receive values in [0,0, 0.45], which is not a very useful information.

#### Common Sense Examples

We categorize classes (e.g. Germans, birds, etc) by typical properties.  
Nevertheless in many cases there will be no individual in the class, who owns all the typical properties. That means formally, that  
'P(a → b∧c∧d...)'  
may be 0 while the single probabilities  
P(a → b), P(a → c),...

are very close to 1.

An other example is the so called lottery paradox:  
We do not expect a single ticket i to win, i.e. for some small ε  
P(ticket i does not win) = (1-ε)

(written as conditional: P(TRUE → ticket i does win) = (1-ε))  
but if we conclude that the conjunction of all these statements (for different tickets) does not win, we make an error, as  
P(TRUE → (ticket i does not win) and (ticket j does not win) and ...) = 0;  
---

Structure of the Cost Matrix  
**Explanation of the Cost Matrix**  
Our choice for translating probabilities into decisions can be described by searching for the decision, for which the expected average costs are minimal.  
For this goal we let the individual positions of our matrix describe the **costs** (theoretical, global, independent of institutions) , given by an actual fault situation and an actual decision.

| Hypotheses and Decisions                                                                                                                                                                                      | (Certified) Fault:     |                                     |                                     |
|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------|-------------------------------------|-------------------------------------|
|                                                                                                                                                                                                               |                        | Fault 1                             | Fault 2                             |
|                                                                                                                                                                                                               | Decision / Treatment 1 | Costs of Treatment 1, given Fault 1 | Costs of Treatment 1, given Fault 2 |
|                                                                                                                                                                                                               | Decision / Treatment 2 | Costs of Treatment 2, given Fault 1 | Costs of Treatment 2, given Fault 2 |
| (NB: Under 'Certified Fault' it is also possible here to find the term 'no fault', correspondingly under the term treatment in also included the decision 'no treatment' An (invented) Example with numbers : | Decision / Treatment 3 | Costs of Treatment 3, given Fault 1 | Costs of Treatment 3, given Fault 2 |

|                        | Fault / Certified Diagnosis 1 | Fault / Certified Diagnosis 2 |
|------------------------|-------------------------------|-------------------------------|
| Decision / Treatment 1 | 2500                          | 3000                          |
| Decision / Treatment 2 | 4000                          | 3000                          |
| Decision / Treatment 3 | 2000                          | 7000                          |

From this matrix can be calculated 'the additional costs of non-optimal decisions' when the smallest respective element of the column (that describes the treatment of choice when the fault associated to the column is present) is subtracted from all the elements.

|                        | Fault / Certified Diagnosis / 1 | Fault / Certified Diagnosis / 2 |
|------------------------|---------------------------------|---------------------------------|
| Decision / Treatment 1 | 500                             | 800                             |
| Decision / Treatment 2 | 2000                            | 0                               |
| Decision / Treatment 3 | 0                               | 4000                            |

When Fault 1 is evident, then it is clear that the correct choice is **treatment 3**. Compared with **Fault 2**, where the obvious choice is **treatment 2**. What meaning can the **treatment 1** have ? This example already shows that the uncertainty alone about the fault in question can lead to a choice of new treatments: When we add to the matrix the probability, that a specialist in a specific situation classifies the existing faults and we accept the specialist holds fault one only to be more likely than Fault 2 (which we would formalize as a probability of 60 % to 40 %) when we further extend the matrix to the calculation of the average costs by a corresponding treatment, then we get th following extended matrix:

| Probability of the Certified Diagnosis | Fault / Certified Diagnosis 1 | Fault / Certified Diagnosis 2 | average costs per treatment |
|----------------------------------------|-------------------------------|-------------------------------|-----------------------------|
| 60 %                                   | 40 %                          |                               |                             |
| Decision / Treatment 1                 | 500                           | 800                           | 0.6 *500 + 0.4 * 800 = 620  |
| Decision / Treatment 2                 | 2000                          | 0                             | 0.6 * 2000 + 0.4 * 0 = 1200 |
| Decision / Treatment 3                 | 0                             | 4000                          | 0.6 * 0 + 0.4 * 4000 = 1600 |

Here is the **treatment 1** the right alternative, as it leads to a cost of 620 units, while treatment 2 in this situation costs 1200 units and treatment 3 1600 units. (We want to point out again, that here the term 'cost' include later effects and other risks.)



NEUDORFER, and C. T., 1987, à € T., 1990, à € œThe probability such as Lógicaà € , in the most maximum-Entropià and Bayesian, P. scully, and M. Table of preimpulse and content table 1 Plausible reassinnance 2 QUANTITATIVE RULES 3 Elementary sampling theory Figure 3-1 4 GRANEMENTAL HYPOTHESIS TESTS 4-1 5 Uses of Queer Probability - The Entropy Principle 13 Decision Theory - Historical Background 14 Simple Applications of Decision Theory 15 Paradoxes of Probability Theory Figure 15 -1 16 Orthodox Methods: Historical Background 17 Principles and Pathology of Orthodox Statistics 18 The AP Distribution and Rule of Succession 19 Physical Measurements 20 Trend and Seasonality In Time Series 21 Return and Linear Model 24 Model Comparison Multivariate accumulators Gaussian Integral The rules of probability can be interpreted as unique principles in the libic. Petroni, M. T., 1959, à € œNet on the unique decipherability, € , I will be translated, on theory of information, IT-5, 98. 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