Information support system for management decisions in the agricultural sector

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Abstract. There is a need in modern agriculture to automate many processes, including automation of taking decision or the providing of current information for taking decisions by responsible person. The aim of the project is to automate the control of the growth of crops or livestock with the help of various devices, such as sensors of various types, analyzing the microclimate of the site according to such characteristics as humidity, air temperature, ground, RFID - tags, GPS - module for analyzing the location of livestock on the farm and intelligent information system that processes the data coming from sensors. The emergence of smart agriculture (Internet of things in agriculture) will facilitate taking decision for owners and responsible persons. Decision making is also facilitated by the quality interface of the information system, which includes the characteristics of data from all types of devices. An additional factor complicating making decision is the ambiguity of the data, which in turn leads to some conflicts. A Petri nets-based model can be used to model and analyse risks. Analysing the model using Petri nets, it can be argued that it is a powerful modelling tool and can be useful in the agricultural sector for selecting the best element from the set, or modelling of data flows.

1. Introduction

The world's population is growing. In 30 years, humanity will need 1.7 times more food than it currently produces. To do this, we need to seriously modernize agriculture.

According to the UN forecasts, the world population by 2050 will reach 9.8 billion people. To feed it, it is necessary to increase food production by 70%.

This means that a soybean farmer in Iowa or a corn farmer in Russia must change production processes to make it as efficient as possible.

"The analogue period in agriculture is over, the industry has entered the digital era". - Goldman Sachs predicts that the use of new generation technologies can increase the productivity of world agriculture by 70% by 2050.

Agriculture is on the threshold of the "Second green revolution". Experts suggest that thanks to precision farming technologies based on the Internet of things, a surge in yields may follow.

Technologies have evolved, become cheaper and advanced to such a level that for the first time in the history of the industry it became possible to obtain data about each agricultural object and its environment, to calculate mathematically accurately the algorithm of actions and to predict the result.

Digitalization and automation of the maximum number of agricultural processes is included as a conscious necessity in the development strategy of the largest agricultural and engineering companies in the world.

By 2010, there were no more than 20 high-tech companies in the world in the field of agriculture, and for the period 2013-2016 years, investors have invested more than 1300 new technology start-ups totalling more than $11 billion for 4 years. A new investment segment AgroTech was formed, which in 2014 overtook FinTech. Moreover, Canada, India, China, Israel are showing noticeable activity in addition to the United States.

The long value chain of agricultural products and the large number of unsolved problems in the industry that can be solved with the help of IT and automation is one of the main arguments in favour of the investment attractiveness of the industry.

Agricultural production is the most vulnerable business, as it is highly dependent on weather and natural phenomena. Unlike traditional production in agriculture, it is impossible to structure all business processes in advance.

The standard treatment schedule (continuous watering, fertilization, chemicalization) does not take into account local features and natural variability and leads to an inefficient result – resource overruns or undetected problems. Drought or excess moisture, lack or excess of fertilizer norm, weeds and insects require immediate intervention. An outbreak can occur unexpectedly and it is not always easy to determine its cause; if detected late and handled incorrectly, the disease can destroy part of the crop.

During the season, the farmer has to make more than 40 different decisions: what seeds to plant, when to plant, how to handle it, how to treat a diseased plant, etc., how to cope with situations that threaten the well-being of the field. Lack of information for taking decisions leads to the fact that in the process of planting, growing, caring for crops up to 40% of the crop is lost. Another 40% is lost during harvesting, storage and transportation.

At the same time, as scientists have identified, in addition to the weather, 2/3 of the loss factors today can be controlled by automated control systems (Hi-Tech Management).

2. Main part

The task of IT becomes the maximum automation of all stages of the production cycle to reduce losses, increase business productivity, optimal resource management. But even in this case, the result applies only to plants ready for harvest or animals, but does not guarantee a profit, because the crop still needs to be collected, stored, carried out primary processing and transported to the buyer/ consumer. Further automation is a higher level of digital integration, which affects the most complex organizational changes in the business, but its implementation can dramatically affect the profit and competitiveness of products and the company as a whole. Integrating the resulting data with a variety of intelligent IT applications that process it in real time is a revolutionary shift in taking decision for the farmer, providing the results of multiple factors analysis and justification for follow-up actions. At the same time, the more detectors, sensors and field controllers are connected to a single network and exchange data, the more intelligent the information system becomes and the more useful information for the user it is able to provide.

Based on scientific calculations, the information system is able to create recommendations for the treatment and care of plants or instructions for automatic execution of its own robotic equipment. For example, a predictive analytical model helps determine that a 2-degree increase in temperature contributes to the hatching of insects, or an increase in humidity above the optimal limit can lead to an outbreak. Management of these factors creates a real value of modeling of microclimatic conditions: if it is a greenhouse, it is possible to prevent temperature rise, and if it is the field-it is prudent to observe the site and act with a chemical when parasites appear. For the first time in the history of agriculture, the farmer has the opportunity to control natural factors, to design accurate business processes, and, in addition, to predict the result with mathematical accuracy.

There are also many changes in livestock. Taking into account the duration of the livestock cycle, systems for proactive analysis of extended production indicators are developed and implemented. This allows the transition from incident management of production process to proactive.

Agriculture is becoming a sector with a very intensive data flow. Information comes from a variety of devices located in the field, on the farm, from sensors, agricultural machines, weather stations, drones, satellites, external systems, partner platforms, suppliers. Common data from different participants of the production chain, collected in one place, allow to obtain information of new quality, to find patterns, to create added value for all involved participants, to apply modern scientific methods of processing (data science) and on its basis to take the right decisions that minimize risks, improve manufacturers' business and customer experience.

Farmers, agronomists, consultants are available mobile or online applications that when you download data about your field (coordinates, area, type of crops, past yields) provide accurate recommendations and sequence of actions, taking into account the analysis of many historical and current factors, both on your site and in the external environment, combining data from machinery, sensors, drones, satellites and other external applications. Now the program helps to determine the best time for planting seeds, fertilizer, moisture or harvest, calculate the time of loading and delivery of the goods to the buyer; monitor the temperature in the storage and transportation area to avoid spoilage and deliver fresh products; predict the yield and income and receive advices on improving the processing of plants in comparison with past performance.

For better modelling, it is necessary to choose a mathematical model that would meet the following necessary characteristics: it could work with both clear and fuzzy values; vary depending on the conditions or characteristics of the object; it could be easy to understand for non-experienced users. Such characteristics are suitable Markov's models including modified Petri net.

3. Mathematic model

Fuzzy hierarchical Petri nets are a bipartite oriented graph. It is a combination of two types of objects, namely positions and transitions, represented as circles and rectangles, respectively. Positions may contain a marker associated with a confidence level, which looks like a value point in the range [0.1]. Directional arcs connect input positions with transitions and transitions to outputs. Each transition contains the value of the certainty factor (μ), which is in the interval [0.1] and the threshold value (τ). The transition is triggered if $\mu > \tau$. After the transition is triggered, the marker is transferred from the input transition to the output transition, pre-calculating under transition the output position. The structure of the FPN is defined by 9 parameters.

$$FPN = (P, T, I, O, D, W, U, Th, M)$$

where:

P = (p1,p2,…pm) finite set of positions. Each element pi=(pi1;pi0) consists of pi1 - direct positions, and pi0- inverted position; with the condition pi=pi1 ∪ pi0;

T = (t1, t2,…tn) - finite set of transitions;

I: P×T→[0,1] is the input matrix with order m × n.

If the position pi is connected by an arc with the transition tj, then the element of the matrix I, Ii j = 1, otherwise Iij = 0;

O: T×P→[0.1], the output transition function with order m × n. If the transition tj are connected by an arc with position pi, then the matrix element of O, Oi j = 1, otherwise Oij= 0;

D = {d1, d2, ... dm} represents a set of statements ∞:P → [0.1] - a function that displays places of real values within [0 1].

β: P → D - function that displays approval locations.

W: P × T → [0.1] is an input function and is represented as a matrix of size m × n. In the matrix, the input value Wij ∈ [0.1] is the weight associated with the input location. For one transition of the sum of weights for all input places =1.

U: T × P → [0.1] is an output function and is represented as a matrix of size m × n. The input value in the matrix U, $\mu_{ij} \in [0.1]$ is equal to the value of the certainty factor (μ) determining the transition t_j can affect its output locations p_i;

Th: O → [0.1] is an output function and is represented as an m × n matrix, the recording in the matrix $\tau_{ij} \in [0.1]$ shows the output threshold at position p_i from the transition t_j site $\tau_{ij} = \infty$, if it is not an output position.

M dynamic input signal and immediate effects on dynamic behavior of DFP.M = (∞(p1), ∞ (p2) ,..., ∞ (pm))T initial marking is denoted by $M0$ [1-14].

The structure of the Petri net contains only fragments corresponding to the production rules P1, P2, P3, P4, P5:

P1: "IF A, THEN B" ($A \rightarrow B$) (figure 1).
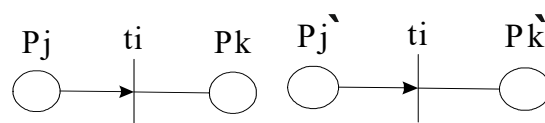
Figure 1. An example of a Petri net formalizing the rule "IF A, then B".

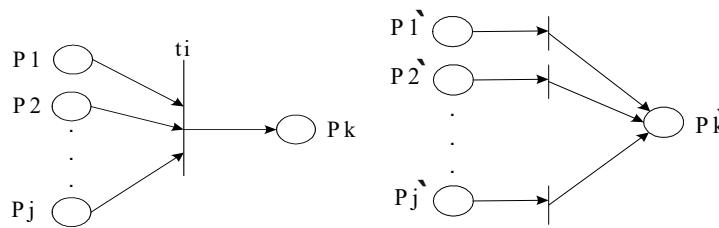P2: "IF A and B and ... and C, THEN D" (A&B&...&C→D) (figure 2);

Figure 2. An example of a Petri net formalizing the rule "IF A and B and ... and C, THEN D".

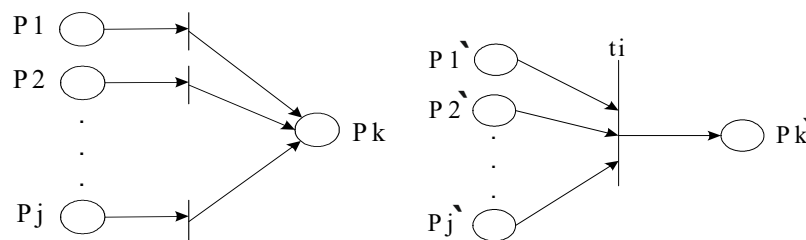P3: "IF A or B or ... or C, THEN D" $(A \vee B \vee ... \vee C \rightarrow D)$ figure 3.

Figure 3. An example of a Petri net formalizing the rule "IF A or B or ... or C, THEN D".

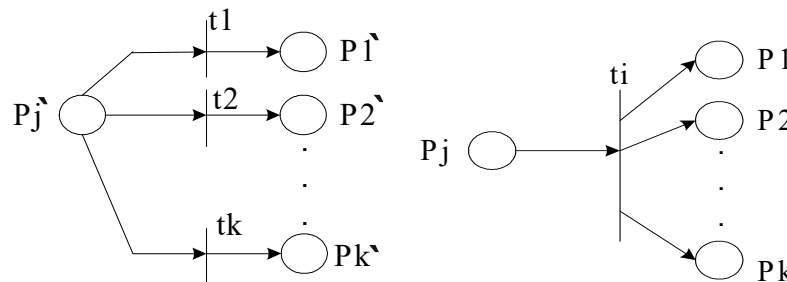P4: "IF A, THEN B and C and ... and D" (A→B&C&…&D) figure 4.

Figure 4. An example of a Petri net formalizing the rule "IF A, THEN B and C and ... and D".

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P5: "IF A, THEN either B or C or...or D" $(A \rightarrow B \vee C \vee ... \vee D)$ figure 5.
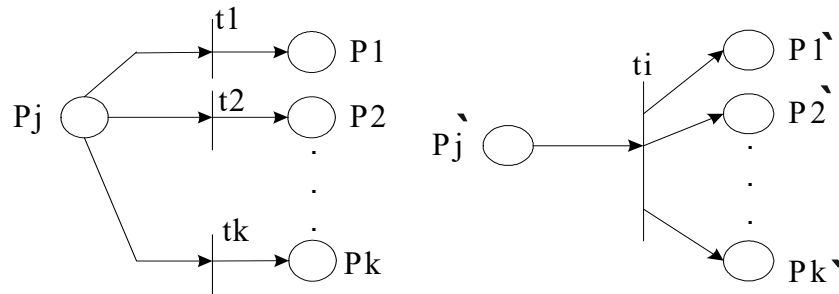

Figure 5. An example of a Petri net formalizing the rule "IF A, THEN either B or C or...or D".

For a particular case, when one transition is triggered, applicable to the rules P1, P2, P3 and P5, the following mathematical calculations are applicable (figure 6):
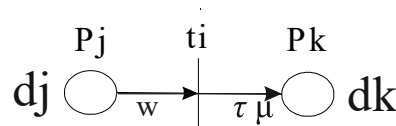

Figure 6. Implementation of the Petri net rule "IF A THEN B".

Here degree of confidence place pj= dj. After triggering, if $\mu > \tau$, the marker is transferred from the position pj to pk and the degree of confidence will be equal to the following:

$$dk = dj \times w \times \mu$$

But figure 7 describes rule 4: if dj then dk1 and dk2 and ... and dkm. Here the switch has several outputs, each output confidence is measured as $dki = dj \times w \times \mu i$.
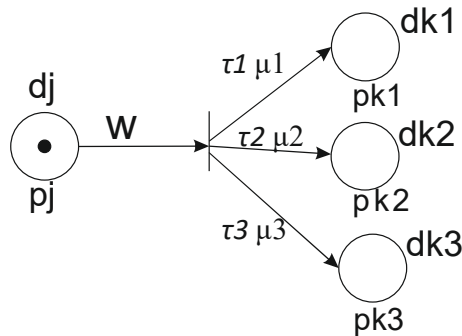

Figure 7. Petri net implementation of the rule "IF A THEN B and C and...and D".

But the transition of the label to any position is not clear. To trigger this type of transition, it is necessary to use mathematical modeling of probabilistic inference based on the maxi-mile logic, Bayesian theory or Dempster – Schafer theory.

According to the theory of fuzzy inference using a maxi-mile model, the inference process is as follows: first, a fuzzy relation is defined representing the inference of knowledge through the max and min operations.

The ratio U is calculated by the formula and can be obtained as:

$$U= [\max[\min(\mu (dk1),\min(\mu(dk2), ... , \min(\mu (dkm),], \max[dk1],\min(\mu(dk2), ... , \min(\mu (dkm],..., \max[dk1],\min(\mu(dk2), ... , \min(\mu (dkm)].$$

Let's consider an example.

For example, crop quality depends on the microclimate and soil fertility: Z-microclimate of the object, R-soil fertility, P-crop quality
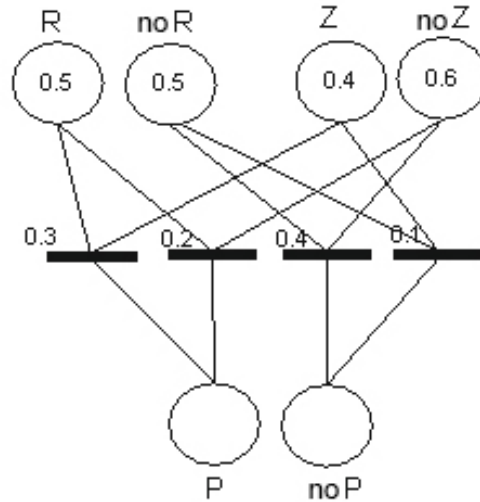
Figure 8. Implementation of the Petri net task.

According to Bayesian theory the probability of influence of soil quality on yield:

$$P(R|Z)=P(Z|R)*P(R)/P(Z)$$

$$P(Z)=P(Z \& R)+P(Z \& HE\ R)$$

If the yield statistics are known, from the probabilistic scheme [1-5]

Table 1. Probability.

R	Z	Probability
t	t	0.3
t	f	0.2
f	t	0.1
f	f	0.4

Table 2. Probability of Exodus.

Probability of Exodus / Mathematical Methods	Bayesian theory	Maximile theory	Dempster – Schafer theory
P(R|Z)	0.75	0.4	0.2
P(Z|R)	0.5	0.5	0.2
P(R|HE Z)	0.333333333	0.6	0.3
P(HE Z|R)	0.4	0.5	0.24
P(HE R |Z)	0.2	0.4	0.2
P(Z|HE R)	0.25	0.5	0.2
P(HE R| HE Z)	0.8	0.6	0.3
P(HE Z| HE R)	0.666666667	0.5	0.3

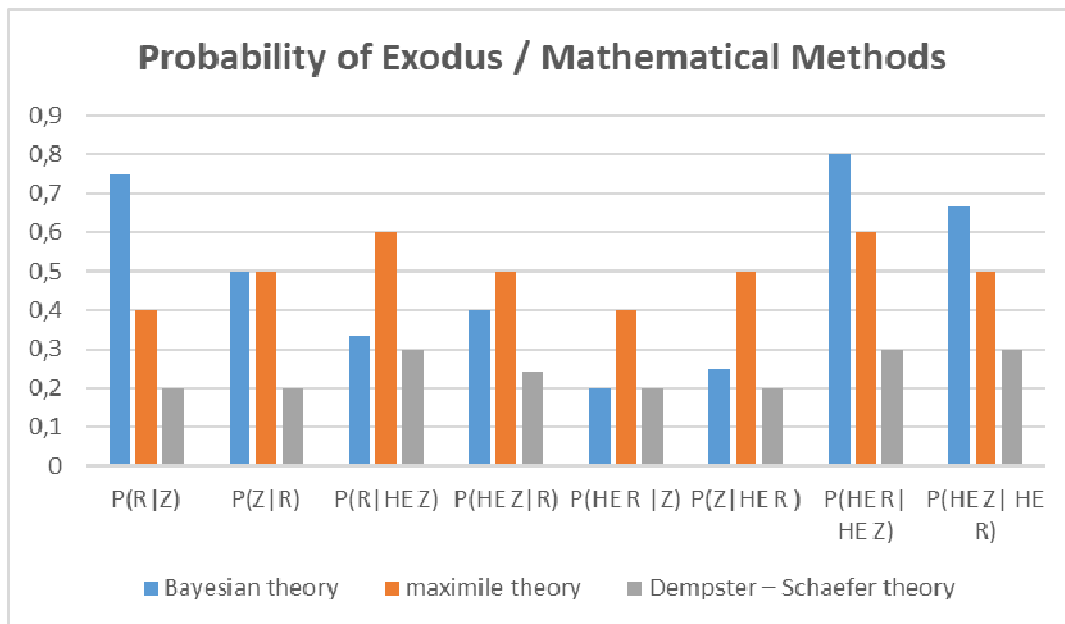Imagine the probability diagram of the outcome (figure 9)

Figure 9. Probability of outcome using Bayes, maxi-mile, and Dempster-Schafer theorems.

A confidence coefficient is a number that indicates the probability or degree of confidence with which a given fact or rule can be considered reliable or fair. This coefficient is an assessment of the degree of confidence in the decision issued by the expert system. The confidence coefficient is applicable to Bayes theory and to the maxi-mile. KU, MD, MND are not probabilistic measures. KU varies from-1 to +1: absolute lie and absolute truth; and 0-means complete ignorance. The MD and MND values range from 0 to 1. The use of KU makes it possible to order hypotheses according to its validity.

$$KU=MD-MND,$$

where KU is the coefficient of confidence in the indicators, taking into account expert evidence;

MD - a measure of trust for given indicators by experts;

MD= min $(p_1,p_2,..p_n)$ with $p_1\&p_2\&…\&p_n$;

MD= max $(p_1,p_2,..p_n)$ with p_1 or p_2 or … or p_n;

MND – measure under given indicators by experts;

MD= max $(p_1,p_2,..p_n)$ with $p_1\&p_2\&…\&p_n$;

MD= min $(p_1,p_2,..p_n)$ with p_1 or p_2 or … or p_n.

Thus, KUB = 0.8-0.2=0.6.

KUM=0.6-0.4=0.2

That suggests about partial or significant confidence in the indicators of experts.

For the Dempster-Schafer theorem, the High confidence of an empty set P(HE R| HE Z) =0.3+0.3 = 0.6 implies the existence of a conflict of evidence on the set of confidence measures in the example given incomplete data for the simulation.

Often Bayesian methods are used in abductive analysis (Abduction is a kind of logical conclusion with the peculiarity that from the premise, which is a conditional statement, and the conclusion follows the second premise). In General, networks using Bayesian logic have a small number of branches. Petri nets using Bayesian logic are acyclic, causes and effects are separated, the net is divided into independent subunits and becomes hierarchical. The advantage of such networks is that it is a visual model that is easy to get from an expert.

4. Conclusion

Thus, it is possible to choose the optimal mathematical model depending on the mathematical methods used in the Petri net transitions. Using a particular model in an intelligent system when removing sensors can bring the conditions to the optimum and get high yields.

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