PROFITABILITY RANKING OF PRECISION AGRICULTURE MEASUREMENT SYSTEM IMPLEMENTATION

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Abstract. Precision Agriculture (PA) methods are adapted to various agricultural branches. One of the PA tasks is to continuously collect real time data about agricultural objects to monitor the object behavior and state of development to recognize any anomalous event or important state. In many cases the objects could have many different important parameters and the farmer has to decide which parameter should be monitored and which measurement system implementation will give the best return of investments (ROI). A formal method for profitability ranking of precision agriculture measurement system implementation is proposed. The method calculates the ROI coefficient of measurement system implementation taking into account gains and/or losses of recognition of different object states, the expected frequency of events, probability of their correct remote recognition by a particular measurement system and the costs of the system implementation. The unit of ROI is a number of years, and it expresses how fast investments for implementation of the specific measurement system will be returned. Based on the proposed method the farmer will be able to evaluate all theoretically possible measurement systems and evaluate which one is more suitable and more effective for practical implementation. The proposed method can be used in different precision agriculture branches. The method is demonstrated on an example from Precision Beekeeping (Precision Apiculture) field ranking bee colony level measurement and monitoring systems for remote recognition of swarming, theft and death of honeybee colonies. Software SEPA (System Evaluator for Precision Agriculture) for support of the proposed method is demonstrated.

Keywords: Precision Agriculture, Precision Beekeeping, measurement systems, system evaluation.

Introduction

Precision Agriculture (PA) can be named and defined in many ways, but the main idea remains to concentrate on the status and needs of agricultural units. Precision agriculture concentrates on providing the means for observing, assessing and controlling agricultural practices. It covers a wide range of agricultural concerns from daily herd management through horticulture to field crop production [1-5].

Precision agriculture can be considered as a three-stage cycle, Fig. 1. The first stage is used for agricultural object data collection. The second stage is the data interpretation or data analysis to make the decision about the needed actions. The third stage is the application of the decision involving the adjustment of important parameters and/or making the needed operations. This phase also can be called as data utilization, since it is at this point that a decision is made and put into practice [6].

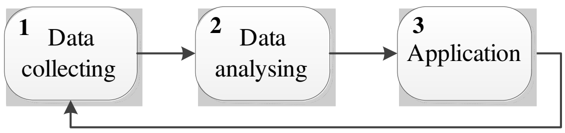

Fig. 1. **Three-stage cycle in PA**

All the mentioned stages are important in PA realization, but the first stage – data collection is the mandatory one for remote monitoring. Many agricultural processes need frequent and even real time data updates. Different measurement systems are needed to measure and collect different parameters of individual agricultural objects to recognize various anomalous or important states of the object development. After the recognition of such states it is needed to take actions to prevent potential loses. In contrast to the automatically and remotely operating measurement system the data analysis and application can be done manually, thus saving the investment costs. Application of various measurement systems can be found in different agricultural branches like Precision Viticulture [7-9], Precision Farming [10; 11], Precision Livestock Farming [12], Precision Horticulture [13], Precision Beekeeping [14]. As a consequence, there is a growing need to monitor many variables during the entire agricultural production process in order to reach the basic targets, like to produce more qualitative products cheaper. It means that sustainable agriculture should operate with a profit.

Therefore, the rate of the return of investment for various precision agriculture events and measurement systems implementation is chosen as a criterion.

So the main question is how to evaluate the effectiveness of the PA events taking into account economic aspects. This economical evaluation should help estimate the profitability of implementation of particular PA systems. The main problem is to conclude which systems and which agricultural object parameters should be automatically measured and monitored. The authors of the paper propose a formal method to evaluate different measurement systems based on return of investment calculations.

Description of formal method

The proposed method is used to determine the return of the investment ratio in years for the implementation of the object parameter measurement system assuming that data analysis and application are carried out manually the way as it is done before the implementation of the automatic measurement system. The proposed algorithm (Fig. 2) is not specific for one branch, but can be used in various agricultural branches.

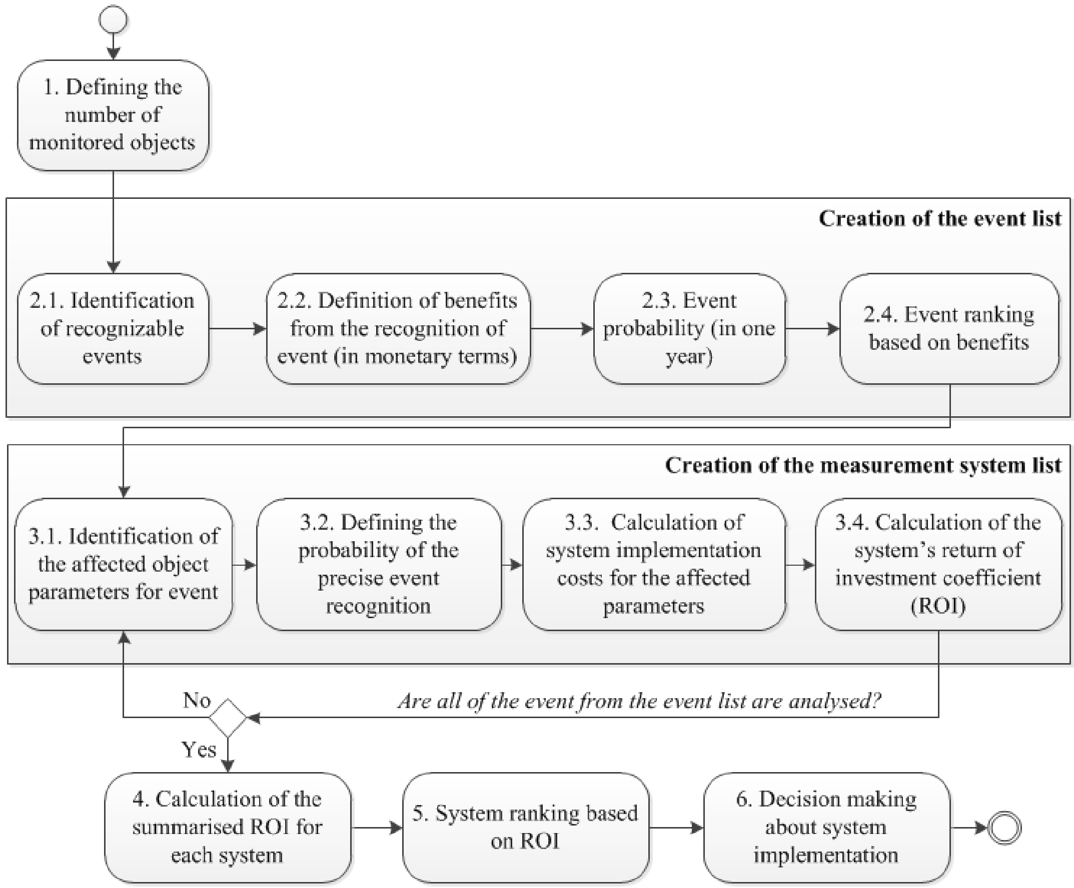

Fig. 2. **Algorithm of formal method for evaluation of measurement systems in PA**

At the beginning (step 1) the user (agricultural specialist) should define how many objects must be monitored with the measurement system.

At the next stage (step 2.1 to 2.4) it is needed to create a list of potential events (object states), which should be recognised. The list should contain information about the benefits from the event recognition (in units of money) and probability of the occurance of the event. The list can be ranked based on the amount of the benefit of its recognition.

At the next third stage (step 3.1 to 3.3) it is needed to cyclically analyze all defined events. For each event it is necessary to define the affected object parameters (one or many) which can be used to recognize the specific event. Then, based on expert knowledge or the previous experiments, it is needed to define probability for the precise recognition of the event using the chosen object parameter. Then the implementation costs of one specific measurement system for monitoring the object parameter have to be calculated. The costs of the measurement system can be divided into three parts: sensor costs; costs for the system part, which depends on the sensor count (for example, specific interface device, for sensor data transferring to the end PC) and costs for the system part, which does not depend on the sensor count (for example PC).

Afterwards (step 3.4) it is possible to calculate the return of the investment coefficient for the implementation of the parameter measurement system using Formula 1.

$$IAK = \frac{SI}{Ieg * ObjSk * Nprob * NAprob} \quad (1)$$

where *SI* – costs for measurement system implementation;
Ieg – benefits from one event recognition;
ObjSk – object count;
Nprob – probability of event in one year period;
NAprob – probability of precise event recognition;
IAK – return of investment coefficient (in years).

At the next, fourth stage (step 4), when all of the events are analysed, it is needed to calculate summirised return of the investment coefficient for each unique measurement system, because a situation is possible when one measurement system can be used to recognise various different events. To do this Formula 2 can be used.

$$IAK = \frac{SI}{\sum Ieg * ObjSk * Nprob * NAprob} \quad (2)$$

Then all measurement systems can be ranked based on the ROI coefficients (step 5) and the user can choose the sequence of implementation of the systems (step 6). In case of limited financial resources a compromise between ROI and the size of investment has to be chosen.

Practical example of calculations based on proposed method

As mentioned earlier, the proposed method can be used in different agricultural branches. The authors choose the beekeeping branch to practically demonstrate the proposed formal method and calculations (see Tables 1-4). All chosen numbers and probability coefficients are approximate and used for illustration purposes. While the detection opportunities of particular events are described in the literature [15-18].

Step 1. The number of monitored objects is 10 (bee colonies).

Table 1

Steps 2.1-2.4 – creation of the event list

Event name	**Benefits from event recognition for one object (in LVL)**	**Benefits from event recognition for all objects (in LVL)**	**Probability of the event in one year**
Bee colony is stolen	80	800	0.1
Death of the bee colony	50	500	0.2
Swarming of the bee colony	25	250	0.5

Table 2

Steps 3.1-3.3 – creation of the measurement system list

List of affected parameters	**Probability of precise recognition of the event**			**Costs for measurement system implementation (in LVL)**
	Bee colony is stolen	Death of the bee colony	Swarming of the bee colony	
Temperature	0.2	0.8	0.6	200
Sound	0.4	1	0.4	300
Video	1	-	-	120
Weight	0.6	-	-	1000

Table 3

Step 3.4 – alculation of ROI coefficients for each event and system

Measurement system	Bee colony is stolen	Death of the bee colony	Swarming of the bee colony
Temperature	12.5	2.5	2.67
Sound	9.375	3	6
Video	1.5	-	-
Weight	20.83	-	-

Table 4

Steps 4 and 5 – calculation of summarised ROI for each unique system

Measurement system	Summarized ROI coefficient (in years)
Temperature	1.17
Sound	1.65
Video	1.50
Weight	20.83

In the demonstrated example the implementation of the temperature measurement system is the most economically beneficial and investments will be returned in 1.17 years or approximately in 14 months time.

SEPA (System Evaluator for Precision Agriculture): Software for calculations of ROI

The authors also developed application to ease the calculations of the ROI coefficients for the specific branch (application available at: http://www.ccsystems.lv/software/sepa). The application consists of 4 modules, which are based on the above described method. The first module is used to create a list of the recognizable events. The second module is used to create a list of the measurement systems, Fig. 3. That is needed to calculate the needed investments for each system. The authors propose to split the investments in three parts:

- sensor price – price for one sensor;
- system part – costs, which are related with the specific system part, which depends on exact number of sensors;
- additional costs – it is needed to take into account any additional possible costs (for example, operational costs).

The third module is used to create all possible combinations, where one event can be recognized with different systems. After that software will calculate ROI for each system and summarize ROI for each particular system, Fig. 4. The application also has an additional configuration module, which is used to complete some administrative functions, like backup of the database.

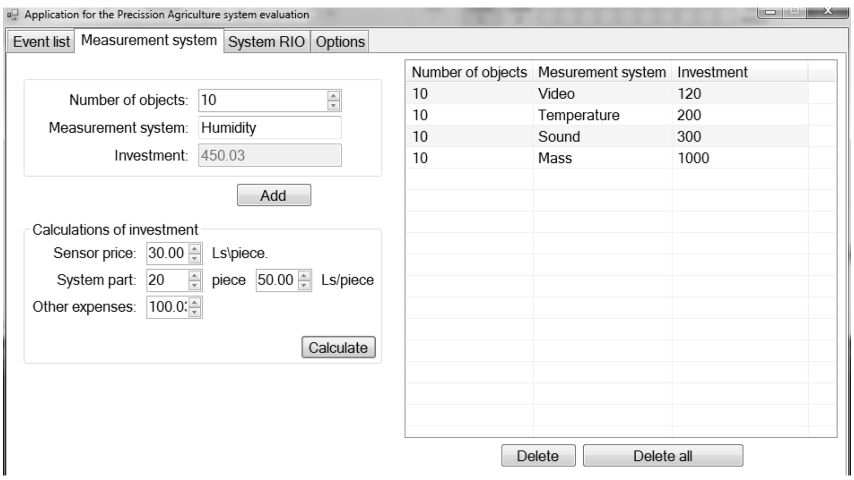

Fig. 3. **Screenshot of SEPA application: module for creating the list of measurement systems**

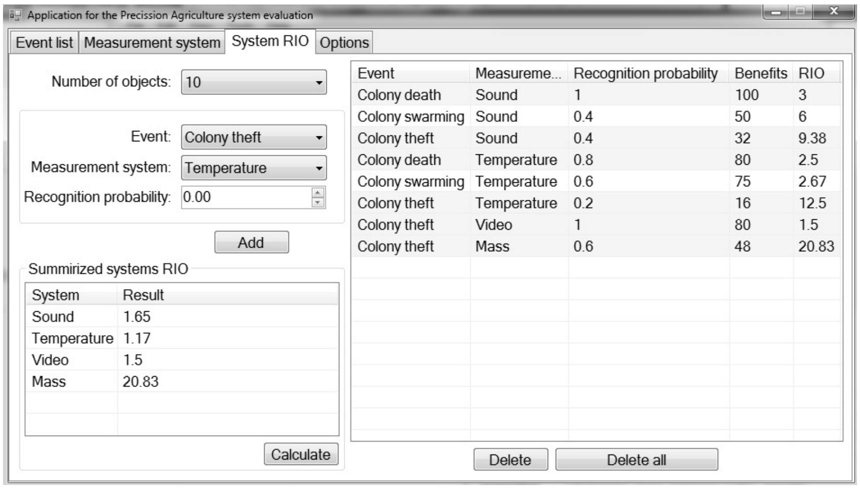

Fig. 4. **Screenshot of SEPA application: module for system ROI calculations**

Conclusions

The developed method for rational measurement system implementation evaluation in Precision Agriculture ranks different measurement systems taking into account the costs of system implementation, probability of correct event recognition, probability of event in one year period as well as a possibility to detect different events with the same system. The proposed method can be used to evaluate various measurement systems in different branches of agriculture.

Both, the return of investment and the amount of investment can be used as a combined criterion prioritizing the implementation of particular measurement systems.

The method can be extended to take into account also automatic decision support systems and automatic application systems. In that case the increased costs of the system can be justified by reduction of the needed human resources to operate the agricultural business unit.

Based on the evaluation agricultural specialists can choose the suitable measurement system for agricultural object individual monitoring.

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References

1. Whelan B., McBratney A. The “null hypothesis” of precision agriculture management. Precision Agriculture, Journal, Vol. 2, 2000, pp. 265-279.
2. Proffitt T., Bramley R., Lamb D., Winter E. Soil sensing in precision viticulture-A new era in vineyard management and wine production. Winetitle, Journal, 2006, pp. 51-55.
3. Morais R., Fernandes M. a., Matos S.G., Serôdio C., Ferreira P.J.S.G., Reis M.J.C.S. A ZigBee multi-powered wireless acquisition device for remote sensing applications in precision viticulture. Computers and Electronics in Agriculture, Journal, Vol. 62(2), 2008, p. 94-106.
4. López Riquelme J.A., Soto F., Suardíaz J., Sánchez P., Iborra A., Vera J.A. Wireless Sensor Networks for precision horticulture in Southern Spain. Computers and Electronics in Agriculture, Journal, Vol. 68(1), 2009, pp. 25-35.
5. Mancuso M., Bustaffa F. A wireless sensors network for monitoring environmental variables in a tomato greenhouse. Proceedings of International conference "The 6th IEEE International Workshop on Factory Communication Systems", June 28-30, 2006 Torino, Italy, 2006, pp. 107-110.
6. Terry B. Thomson Delmar learning. Precision Agriculture, Journal, 2006, p. 224.
7. Bramley R., Hamilton R. Understanding variability in wine grape production systems. Australian Journal of Grape and Wine Research, Journal, vol. 10(1), 2004, pp. 32-45.

8. Morais R. Fernandes M. a., Matos S. G., Serôdio C., Ferreira P. J. S. G., Reis, M. J. C. S. A ZigBee multi powered wireless acquisition device for remote sensing applications in precision viticulture. Computers and Electronics in Agriculture, Journal, vol. 62(2), 2008, pp. 94-106.
9. Santesteban L. G., Guillaume S., Royo J. B., Tisseyre B. Are precision agriculture tools and methods relevant at the whole-vineyard scale? Precision Agriculture. Journal, 2012, doi:10.1007/s11119-012-9268-3.
10. Auernhammer H. Precision farming — the environmental challenge. Computers and Electronics in Agriculture, Journal, vol. 30(1-3), 2001, pp. 31-43.
11. Reichardt M., Jürgens C. Adoption and future perspective of precision farming in Germany: results of several surveys among different agricultural target groups. Precision Agriculture, Journal vol. 10(1), 2008, pp. 73-94.
12. Berckmans D. Automatic on-line monitoring of animals by precision livestock farming. Livestock production and society, 2006, pp. 51-54.
13. Zhou R., Damerow L., Sun Y., Blanke M. M. Using color features of cv. "Gala" apple fruits in an orchard in image processing to predict yield. Precision Agriculture, Journal, vol. 13(5), 2012, pp. 568–580. doi:10.1007/s11119-012-9269-2.
14. Zacepins A., et al. Application of information technologies in precision apiculture. "The 13 International Conference on Precision Agriculture". Indianapolis, USA. 2012. Paper 1023.
15. Zacepins A., Meitalovs J., Komasilovs V., Stalidzans E. Temperature sensor network for prediction of possible start of brood rearing by indoor wintered honey bees. "The 12th International Carpathian Control Conference (ICCC 2011)". Velke Karlovice, Czech Republic, 2011, pp. 465-468.
16. Zacepins A., Stalidzans E. Architecture of automatized control system for honey bee indoor wintering process monitoring and control. "The 13th International Carpathian Control Conference (ICCC 2012)". Podbanske, Slovakia, 2012, pp. 772-775.
17. Zacepins A. Application of bee hive temperature measurements for recognition of bee colony state. "The 5th International Scientific Conference "Applied Information and Communication Technologies" (AICT 2012)". Jelgava, Latvia, 2012, pp. 216-221.
18. Stalidzans E., Berzonis A. Temperature changes above the upper hive body reveal the annual development periods of honey bee colonies. Computers and Electronics in Agriculture, Journal, Vol. 90, 2013, pp. 1-6.