User-Technological Index of Precision Agriculture

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Abstract

User-Technological Index of Precision Agriculture (UTIPA) is a comprehensive system based on mutual sharing of opinions and experience within community of people related to precision agriculture - farmers, technology suppliers and researchers. The main benefit of UTIPA is the possibility to use the calculated index level for particular technology (method) for precision agriculture and compare it to other technology with regards to different users, crops, regions etc. It evaluates the principle of a technology but does not take into account concrete products, brands or manufacturers. The index has significance for the presentation of the potential of precision agriculture, development planning and especially for the connection between technological innovativeness and usefulness for practice.

The entire solution includes the methodology for the collection, processing and presentation of data and software and is available via a Web interface for all common device platforms. Anyone who has interest in precision agriculture and contributes their knowledge can use the collected data.

Keywords

Precision agriculture, technological sophistication, user accessibility, knowledge sharing.

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Introduction

The increasing population and the associated increasing demands on the efficient utilization of the agricultural potential lead to the incorporation of new technologies in many sectors of agriculture. Along with the rapid climate changes taking place in recent years there is overall change in the conditions and methods of agricultural land use. Emerging countries need to apply the principles of precision agriculture to secure their sustainable development (Shen et al., 2010).

The concept of precision agriculture is in the interest of the professional public since the 1990s. It generalizes the effort to identify solutions, tools and processes that can improve productivity and profitability while protecting the environment (Cambouris et al., 2014). Precision agriculture plays a vital role in increasing production and is seen as part of the agricultural process efficiency and environment-friendliness. In summary, the concept of precision agriculture is based on observations and measurements followed by the appropriate responses - for example through the introduction of new technology or by changing manufacturing processes. Precision agriculture technologies allow farmers to identify problems and opportunities and apply solutions with far greater accuracy (Lindblom et al., 2016).

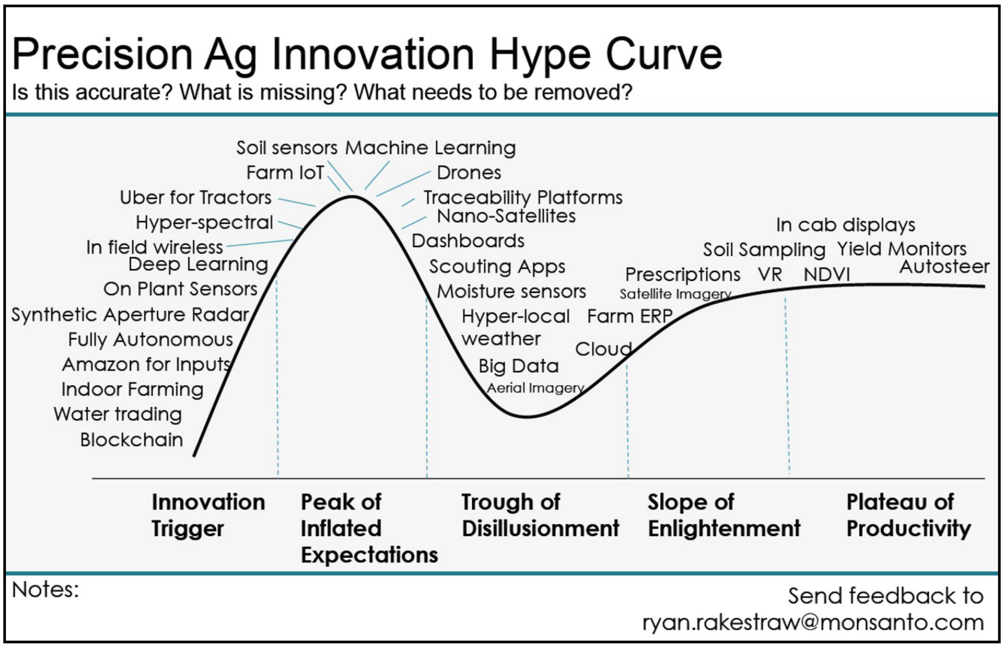
The use of precision agriculture constitutes a crucial role in reducing the environmental burden, especially in reducing the amount of pesticides used. When using precision agriculture it is possible to achieve 8-10% reduction in the volume of pesticides compared to traditional agriculture. Such reduction not only has an impact on the financial cost of production but also for environmental protection (Katalin et al., 2014). In many countries precision agriculture is the only possible starting point for sustainable development. As mentioned by (Akdemir et al., 2014) for example, Turkey has no limits on the use of pesticides and fertilizers and the use of precision agriculture is therefore essential for the future of this country.

Along with the advancement of technology from a technical point of view, it is also necessary to understand the development of technologies for precision agriculture from the user perspective - for example within the field of human-computer interaction (Lindblom et al. 2016). Specifics of interaction between users and technology can then be vital for successful utilization of precision agriculture in practice (Kroulík et al., 2009). In some cases, the user comfort, stress and workload reduction can even be the primary benefit of a particular technology. As demonstrated by (Holpp et al. 2013) using the RTK (real time kinematic) navigation has in addition to improving the accuracy of driving and increasing turn speeds also a major impact on reducing stress for drivers of agricultural machinery.

A key factor in deciding whether a particular technology should be incorporated to practice is the understanding of agricultural production processes. Workers in agriculture management must choose among various options for applied research and technology and in this decision-making process it is the necessary to merge the previous experience of the staff and the introduction of new technologies and procedures (Kumhála et al., 2003). It is vital to establish effective decision models and support resources for that particular phase of the production process. The basic premise for appropriate decision is quick availability of quality data. However, the situation in European agriculture is that most of the data is fragmented and difficult to interpret. The actual potential of data associated with precision agriculture is not fully exploited (Fountas et al., 2015).

Expansion of precision agriculture elements into practice is slow process, as evidenced for example by (Schimmelpfennig and Ebel, 2016). From the perspective of farmers the implementation of precision agriculture technology also represents an important economic decision. The most important factor that can accelerate the application of precision agriculture is profitability or investment rate of return. For efficient transfer of precision agriculture technology into practice it is therefore necessary to ensure farmers' awareness about the economic benefits of these technologies (Katalin et al., 2014). The amount and type of actual real-world technologies and processes is closely related not only to the reasons for deploying these technologies, but especially to economic efficiency (Paustian and Theuvsen, 2016). Different forms of presentation are used to illustrate these phenomena, one example might be a characteristic of technological developments in precision agriculture using hype cycle (Figure 1).

When analyzing current models and procedures for the use of precision agriculture it is necessary to take into account phenomena that primarily lead to the adoption of precision agriculture. Recent studies ignore the information, behavioral and social aspects leading to the decision to use precision agriculture. The studies also ignore the political aspects within which agriculture operates. Understanding these conditions, which may go beyond the primary motivation for using precision agriculture, is essential for a better integration of new technologies in precision agriculture into practice (Tey and Brindal, 2012).



Source: Rakestraw (2016)

Figure 1: Precision Ag Innovation Hype Curve .

Materials and methods

User-technological Index of Precision Agriculture is a complex system that includes a methodology for the collection, processing and presentation of data and software and is available via a Web interface for all common device platforms.

Technical solution

Based on the analyses, UTIPA software solution was developed as a modular web application that reflects the state of the art processes and technology. The app uses freely available software. The portal runs on the Apache Web server and is written in PHP 7 using Nette Framework (Nette Foundation, 2015). Data are stored in a database system MySQL. The technologies Google chart tools (Lee et al., 2014), HTML, CSS and JS Framework Bootstrap are used for graphical visualization of the content.

The user interface is designed using responsive web technologies (Šmejkalova et al., 2015), which allows use of the website on different devices (mobile, tablet, desktop) via a Web browser.

Answer relevance

Data is collected through an online questionnaire, which is available on the Internet, resulting in two major threats to the data base, which is the attack on the questionnaire by a robot (Wang et al., 2015) and the other are users who fill out the questionnaire without sufficient examination. To avert these threats the software solution employs two mechanisms:

- Input data must be verified by clicking on the link in the sent email.
- Work with user questionnaire is constantly monitored by self-learning algorithm that is used to verify the relevance of input data. The principle of the algorithm can not be published for safety reasons.

UTIPA and G-UTIPA calculation

UTIPA (User-Technological Index of Precision Agriculture) is calculated for each technology separately from obtained relevant data. These calculations do not include data from general public. Index consists of two parts, the numeric values and additional character. The numeric part of the index has value between 0 and 1 and reflects the degree of usefulness and sophistication of the technology. The numeric value can be supplemented by character which can be either "u" or "t" and expresses better ranking in favor of usefulness for practice or technological advancement - the location in the chart in Figure 5.

The numeric index is calculated as the sum of averages of responses in technological advancement and usefulness for practice. The result is then normalized to the interval <0-1>. The exact formula for calculating numerical value of UTIPA is as follows:

$$UTIPA = \frac{y_{max} - y_{min}}{x_{max} - x_{min}} \left(\frac{1}{n} \sum_{i=1}^{n} (u_i + t_i) - x_{min} \right)$$

where:

n – number of respondents

u – respondent answer – usability in practice

t – respondent answer – technological sophistication

x_{min} – minimum value of the original interval

x_{max} – maximum value of the original interval

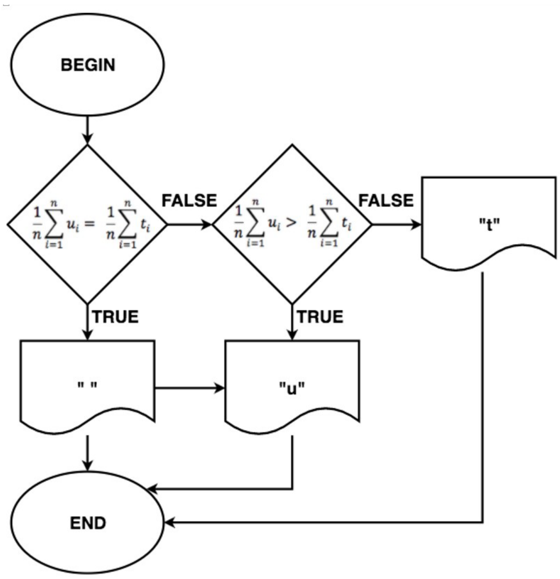
y_{min} – minimum value of the new interval

y_{max} – maximum value of the new interval

Once the minimum and maximum values of the original and the new interval are input into the formula it can be simplified to the following form:

$$UTIPA = \frac{0.125}{n} \left(\sum_{i=1}^{n} (u_i + t_i) \right) - 0.25$$

According to the algorithm in (Figure 2) it is decided whether to use the additional character.



Source: author

Figure 2: The algorithm for making additional character for UTIPA.

n – number of respondents

u – respondent answer – usability in practice

t – respondent answer – technological sophistication

Comparison of assessments

One of the main functionalities of the UTIPA application is that it allows you to view and compare various assessments to each other, for example different groups of respondents, land development over time or own assessment of individual technologies with the assessment of other evaluators. This comparison consists of two parts - the graphical display and a number expressing the distance of the self-evaluation from assessment of other respondents. This distance is calculated by the following formula:

$$d = \sqrt{\left(u_r - \frac{1}{n}\sum_{i=1}^{n} u_i\right)^2 + \left(t_r - \frac{1}{n}\sum_{i=1}^{n} t_i\right)^2}$$

where:

d – distance of own assessment from assessment of other respondents

n – number of respondents

u_r – own answer – usability in practice

u – respondent answer – usability in practice

t_r – own answer – technological sophistication

t – respondent answer – technological sophistication

Results and discussion

The purpose of the "User-Technological Index of Precision Agriculture" is to convey the knowledge of users, suppliers and researchers in the use of modern technology in agriculture. It is primarily based on a five-point evaluation of selected technologies (methods) of precision agriculture in terms of technological advancement and usefulness for agricultural practice. It evaluates technologies in principle and does not reflect specific products, brands or manufacturers.

To achieve the best level of technological sophistication (5 points) evaluated methods of precision agriculture generally need to have proven performance and reliability, contain user interface for use in agricultural practice and have to be mass produced, ideally by several manufacturers. As the worst level in this context (1 point), we consider technologies based only on theoretical considerations.

For the highest level of usefulness for practice (5 points) evaluated methods must show tangible increase in economic efficiency, quality and quantity of production, organization and level of control of the production process, welfare, etc. The perception of the potential of assessed methods for solving production shortcomings of currently used technologies also contributes for higher scores in this regard, as it shows needs for innovation in the production area. The worst level in this evaluation means there is high ambiguity in usage and potential benefits.

Rating is based on individual knowledge and experience of the respondents. An important characteristic of the evaluated technology is also its unfamiliarity among the respondents. The index is calculated on the basis of awarded points and can be used to compare the various technologies, respondent groups, countries and changes over time, etc., but also to compare one's ratings with rating of other respondents. At the same time the obtained values allow for visualization which offers many new insights and findings, e.g. to compare and split rated technologies into four basic groups (Figure 3):

Source: author

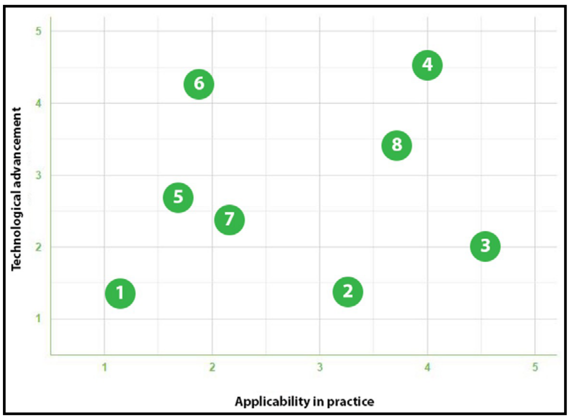
Figure 3: Comparing the potential of technologies in precision agriculture.

- **Vision** - this expresses the intention, finding technological solutions and method of use
- **Potential** - perfect technological solution, the problem is with efficiency and usability
- **The need** - the need in practice, the problem is with technological development
- **Practice** - target state of perfect technological solutions, economic efficiency and high user applicability in practice

Basic forms of presentation of data

Comparing technologies

Basic display of User-Technological Index of Precision Agriculture. The X axis shows the "usefulness in practice" and Y axis shows the "technological advancement." By plotting the values that are statistically treated we get a quick overview diagram for comparing the selected precision agriculture methods and their use in practice (Figure 4).

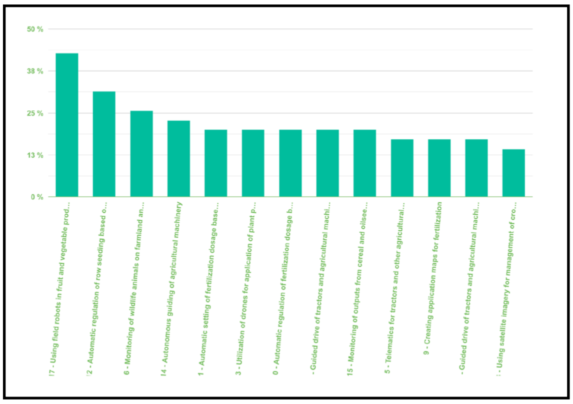


Source: author

Figure 4: Visualization of comparing precision agriculture technologies with UTIPA.

Technology unfamiliarity

UTIPA calculation is based only on assessments that have been assigned points (1-5). A specific evaluation method of precision agriculture is the ratio of respondents who lack the knowledge about a technology and choose the "I cannot judge." option when assigning their evaluation. The output is then a comparison of unfamiliarity of technologies (Figure 5).

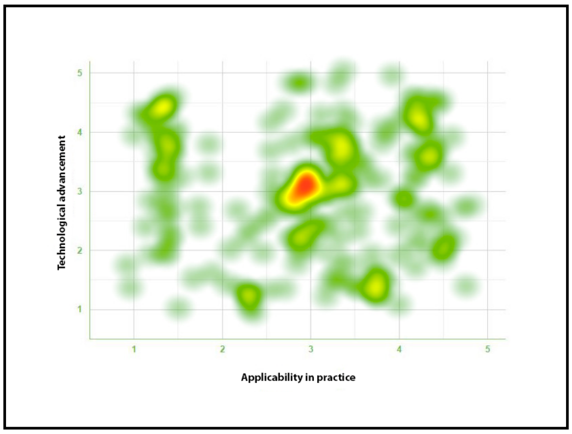


Source: author

Figure 5: Ratio of respondents, who are unfamiliar with given precision agriculture technology.

Rating scattering

The principle of a heatmap is used for graphical presentation of scatter of the individual technology ratings. The red color represents the greatest occurrence, yellow represents successively smaller occurrence and green to turquoise denotes the smallest incidence (Figure 6).



Source: author

Figure 6: Heat map of occurrence of assessments by individual respondents.

Comparing assessments

One of the main benefits of UTIPA is that it allows us to compare the level of use of precision agriculture methods with each other, according to different users, crops, regions etc. In the basic XY chart it displays a color-coded comparison of ratings. Figure. 7 shows the comparison of self-evaluation with the overall average.

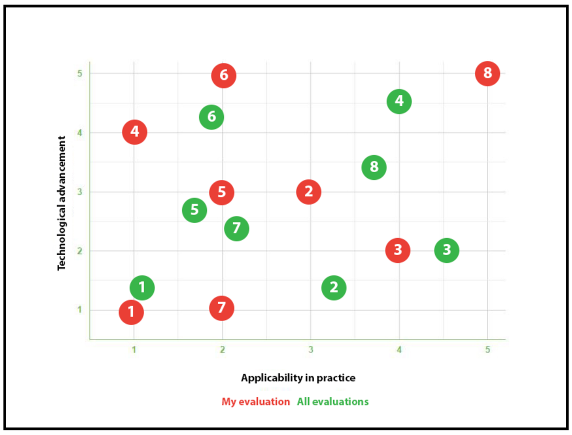


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Figure 7: An example of comparison of assessments from different respondents.

Conclusion

Finding the relationship between technological innovations, economic efficiency and practicality is addressed from the beginning of the development of precision agriculture. There are a number of technologically advanced methods, which did not achieve the expected use in practice. On the other hand, there is real demand of farmers for technological development in many areas. Efficiency and usability depends on local conditions and type of cultivated crops and varies in different countries and evolves over time.

User-Technological Index of Precision Agriculture is a complex system for the international community of people related to precision agriculture, it is accessible to anyone who respects the rules of use. It works on the principle of "what data I provide is the type of data I gain access to". It enables long-term monitoring of developments and trends in precision agriculture. It has significance for the presentation of the potential of precision agriculture, development planning and above all to find the relationship between technological innovativeness and usefulness for practice.

This benefits all the stakeholders. Farmers can find out whether a given technology is useful and has real importance. Suppliers need to know what their customers (farmers) want or expect, but also how they perceive their products. For academia it can be a source of data for science and research. Finally, it can help to raise awareness about the technologies of precision agriculture among professionals.

During following research activities the software solution will continue to be developed. It is expected to include a detailed overview of the various technologies in the web application so that it can be used as a reliable source of information. Visualization will be subject to further research as to deliver significant outputs for individual target groups. One of the goals is to tighten the links and cooperation between farmers, suppliers, academia and the professional community.

UTIPA system is freely available as a web application at **https://www.utipa.info/.**

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References

[1] Akdemir, B., Ungor, M. G., Saglam, N., Aydogdu, B., Belliturk, K., Kesici, E. and Urusan, A. (2014) „Development of a precision farming system for Turkish farmers“, *Acta Horticulturae*, Vol. 1054, pp. 301-308. [Online]. Available: http://www.actahort.org/books/1054/1054_36.htm [Accessed: Jan 20, 2017]. ISSN 0567-7572. DOI 10.17660/ActaHortic.2014.1054.36.

[2] Cambouris, A. N., Zebarth, B. J., Ziadi, N. and Perron I. (2014) „Precision Agriculture in Potato Production“, *Potato Research*, Vol. 57, No. 3-4, pp. 249-262. [Online]. Available: http://link.springer.com/10.1007/s11540-014-9266-0 [Accessed: Jan 15, 2017]. ISSN 0014-3065. DOI 10.1007/s11540-014-9266-0.

[3] Fountas, S., Carli, G., Sørensen, C. G., Tsiropoulos, Z., Cavalaris, C., Vatsanidou, A, Liakos, B., Canavari, M., Wiebensohn, J. and Tisserye, B. (2015) „Farm management information systems: Current situation and future perspectives“, *Computers and Electronics in Agriculture*, Vol. 115, pp. 40-50. [Online]. Available: http://linkinghub.elsevier.com/retrieve/pii/S0168169915001337 [Accessed: Feb 5, 2017]. ISSN 01681699. DOI 10.1016/j.compag.2015.05.011.

[4] Holpp, M., Kroulík, M., Kvíz, Z., Anken, T., Sauter, M. and Hensel, O. (2013) „Large-scale field evaluation of driving performance and ergonomic effects of satellite-based guidance systems“, *Biosystems engineering*, Vol. 116, No. 2, pp. 190-197. ISSN 1537-5110.

[5] Katalin, T. G., Rahoveanu, T., Magdalena, M. and István, T. (2014) „Sustainable New Agricultural Technology – Economic Aspects of Precision Crop Protection“, *Procedia Economics and Finance*, Vol. 8, pp. 729-736. [Online]. Available: http://linkinghub.elsevier.com/retrieve/pii/S2212567114001518 [Accessed: Jan 15, 2017]. ISSN 22125671. DOI 10.1016/S2212-5671(14)00151-8.

[6] Kroulík, M., Kumhála, F., Hůla, J.and Honzík, I. (2009) „The evaluation of agricultural machines field trafficking intensity for different soil tillage technologies“, *Soil & Tillage Research*, Vol. 105, No. 1, pp. 171-175. ISSN 0167-1987.

[7] Kumhála, F., Kroulík, M., Mašek, J. and Prošek, V. (2003) „Development and testing of two methods for the measurement of the mowing machine feed rate“, *Plant Soil Environ*, Vol. 49, No. 11, pp. 519-524. ISSN 1214-1178.

[8] Lee, S., JO, J. and Kim, Y. (2014) "Performance testing of web-based data visualization“, In: *2014 IEEE International Conference on Systems, Man, and Cybernetics (SMC)*, pp. 1648-1653. ISBN 978-1-4799-3840-7. DOI 10.1109/SMC.2014.6974152.

[9] Lindblom, J., Lundstrőm, Ch., Ljung, M. and Jonsson, A. (2016) „Promoting sustainable intensification in precision agriculture: review of decision support systems development and strategies“, *Precision Agriculture*. [Online]. Available: http://link.springer.com/10.1007/s11119-016-9491-4 [Accessed: Jan 10, 2017]. ISSN 1385-2256. DOI 10.1007/s11119-016-9491-4.

[10] Nette Fundation. [Online]. Available: http://nette.org/ [Accessed 12 December 2016].

[11] Paustian, M. and Theuvsen, L. (2016) „Adoption of precision agriculture technologies by German crop farmers“, *Precision Agriculture*. [Online]. Available: http://link.springer.com/10.1007/s11119-016-9482-5 [Accessed: Dec 15, 2016]. ISSN 1385-2256. DOI 10.1007/s11119-016-9482-5.

[12] Rakestraw, R. (2016) „Precision Ag Innovation Hype Curve“. [Online]. Available: https://drive.google.com/file/d/0B0w-0TilL5ROMHA5bm1HS3pycVU/view [Accessed: Jan 9, 2017]

[13] Shen, S., Basist A.and Howard, A. (2010) „Structure of a digital agriculture system and agricultural risks due to climate changes“, *Agriculture and Agricultural Science Procedia*, Vol. 1, pp. 42-51. [Online]. Available: http://linkinghub.elsevier.com/retrieve/pii/S2210784310000070 [Accessed: Jan 10, 2017]. ISSN 22107843. DOI 10.1016/j.aaspro.2010.09.006.

[14] Schimmelpfennig, D. and Ebel, R. (2016) „Sequential Adoption and Cost Savings from Precision Agriculture“, *Journal of Agricultural and Resource Economics*, Vol. 41, No. 1, pp. 97-115. ISSN 1068-5502.

[15] Šmejkalova, M. Benda, P. and Ulman, M. (2015) "Usability and Accessibility analysis of Czech agrarian portals“. In *Agrarian Perspectives XXIV. – Global Agribusiness and Rural Economy*, Prague, pp. 456-462. ISBN 978-80-213-2581-4.

[16] Tey, Y. S., and Brindal, M. (2012) „Factors influencing the adoption of precision agricultural technologies: a review for policy implications“, *Precision Agriculture*, Vol. 13, No. 6, pp. 713-730. [Online]. Available: http://link.springer.com/10.1007/s11119-012-9273-6 [Accessed: Jan 8, 2017]. ISSN 1385-2256. DOI 10.1007/s11119-012-9273-6.

[17] Wang, J., Zhang, M., Yang, X., Long, K and Xu, J. (2015) „HTTP-sCAN: Detecting HTTP-flooding attack by modeling multi-features of web browsing behavior from noisy web-logs“, *China Communications*, Vol. 12, No. 2, pp. 118-128. ISSN 1673-5447. DOI 10.1109/CC.2015.7084407.