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Usage of SIGMO, a Decision Support System for the Assessment of Genetically Modified Organisms in Food and Feed

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ABSTRACT

SIGMO is a web-based decision support system for assessing the probability of existence of a genetically modified organisms in food and feed products imported in the European Union. The system has been developed in the frame of the EU FP7 project Decathlon. In this paper, we describe SIGMO, provide examples of how to use it for training and evaluation purposes, and report the statistics of its actual use.

Keywords

decision support system, qualitative multi-criteria modeling, genetically modified organisms, SIGMO

1. INTRODUCTION

The import of genetically modified organisms (GMOs) in the European Union (EU) has begun in 1994, and since then EU has developed different monitoring mechanisms to assess the risk of entering any GMO in its market. The goal of the risk assessment is to ensure that imported food or feed is safe for human and animal health and the environment. Hence, the EU treats all genetically modified crops (GMO crops) as "a modified food". All GMO crops that are intended to be admitted to the EU, are extensively evaluated by the European Food Safety Authority (EFSA) [1], which reports its findings to the European Commission (EC). The EC then proposes whether to grant or refuse the authorisation for the GMO [2]. In the EU, currently (September 2016) 68 GMOs are authorised in cotton (10 GMOs), maize (36), oil seed rape (6), soybean (15), and sugar beet (1) [3]. Despite the large number of authorized GMOs, the import of non-authorized GMOs is still being detected in EU, in particular from the US, Canada, Argentina, China and Brazil [4]. Whenever a product that contains GMO is imported, this information needs to be provided on the product label. There is a threshold of 0.9% for the adventitious and technically unavoidable presence of authorized GMOs in non-GMO batches that do not require labelling [5, 6].

Regardless of the strict measures, it still happens that products containing GMOs without labeling are imported into the EU. These products can reach the market and then be further on inspected. In cases of finding unauthorized GMOs in products, these will be withdrawn from the market, leading to significant financial losses for the traders. To assist the traders and producers of complex products, whose ingredients may contain GMOs, a decision support system called SIGMO (System for Identification of GMOs) has been developed within the European Framework 7 project 'Decathlon' (http://www.decathlon-project.eu/). In this paper, we describe SIGMO, illustrate its application for training and evaluation through several examples, and report statistics of using the system since it has been made available on-line.

2. SIGMO

SIGMO [6] is a web-based decision support system (DSS) that has been designed to provide help to producers, traders and importers with the aims to:

- reduce the number of necessary GMO analyses;
- better cope with the complexity of GMO market without requiring its users to have extensive knowledge on the world-wide production;
- comply with EU GMO regulations in a cost-effective way.

SIGMO is composed of:

- a data base providing data about GMO crop species produced and approved in counties worldwide;
- a multi-attribute model for the assessment of GMO presence in food/feed products; and
- an on-line user interface available at www.decathlon.ijs.si/gmo/.

2.1 SIGMO database

The SIGMO database consists of tree tables that hold data on countries, the list of possible status types that a GMO-containing product may obtain regarding the GM presence, such as "High likelihood", "Medium likelihood", and "Low likelihood"; and a list of all currently listed GMOs species. These tree tables are connected with three relations. The first relation, which defines the area of a particular crop planted in a certain country, determines if a certain GMO/country pair belongs to a region of increased GMO production. The second relation holds information regarding each particular GMO event. For example, maize may have several gene modifications, each one having a different Event name. Such names would be "MON810" encoded as "MONØØ81Ø-6". Finally, the third one defines a many-to-many relation between Events and Countries, associated with a particular status type. At the current implementation, the database holds over 300 GMOs.

2.2 SIGMO multi-attribute decision model

The central part of SIGMO is a multi-attribute decision model that provides an assessment of the potential presence of GMOs in imported feed or food products. The model has been developed using the methodology DEX (Decision Expert) [7]. DEX belongs to the group of qualitative multi-criteria decision making methods. In DEX, a hierarchical structure containing qualitative attributes is built which represents a decomposition of the decision problem into smaller, less complex and possibly easier to solve sub-problems. There are two types of attributes in DEX: basic and aggregated. The former are the directly measurable attributes, which are used for describing the decision options and represent input data to the model. The latter are obtained by aggregating the basic and/or other aggregated attributes. They represent the evaluations of the options. The hierarchical structure represents the dependencies among attributes such that the higher-level attributes depend on their immediate descendants in the tree. This dependency is defined by a utility function by the expert.

Attribute	Description
GM_Presence	Assessment of GM presence in food/feed products
TraceabilityData	GM presence due to traceability data
Products	GM presence due to product characteristics
ProductGMPresence	Assessment of GM presence in the product
CropGMPresence	Assessment of GM presence related to the crop
GeoGMPresence	Assessment of GM presence related to the geographical origin of the product
EU	Does the product originate in an EU country?
GM_Region	Does the product originate in a region of large GMO production?
ProductComplexity	Product type
Countries	Likelihood of GM presence due to the properties of countries and regions of origin
NumberCountries	Number of countries involved in storage
CountryGMPresence	Likelihood of GM presence with respect to involved countries
CoexistenceMeasures	Are coexistence measures in place in countries?
Transportation	Likelihood of GM presence due to transportation
PrepackagedProduct	Is product prepackaged?
Logistics	Likelihood of GM presence due to logistics
LogComplexity	GM presence due to logistics complexity
NumberInteractions	Number of interactions in the supply chain
NumberCompanies	Number of companies involved in logistics
LogStorage	Likelihood of GM presence due to storage used
Harbour	Has the product been shipped through harbour(s)?
Silo	Has the product been stored in silos?
SystemsUsed	GM presence due to used traceability systems
TraceabilitySystemInPlace	Is a traceability system in place?
IP_GMO	Are IP systems for GMO being used?
IP_Other	Are other IP systems being used?
AnalCtrl_Systems	Are there systems used that include analytical control?
PrivateContracts	Are there any private contracts?
AnalyticalData	GM presence due to analytical data
AnalyticalResults	GM presence according to analytical results
AnalyticalResultsAvailable	Are analytical results available?
ApprovedGMOsIdentified	Approved GMOs identified
UnapprovedGMOsIdentified	Unapproved GMOs identified
Methods	Risk due to applied methods
ProcessingLevel	Processing level
AppropriateSampling	Have appropriate sampling methods been used?
AppropriateMethods	Have appropriate analysis methods been used?
Reliability	Reliability of applied methods
ReliabilityForApprovedGMO	Reliability of applied methods to detect approved GMOs
RelevantGMCropsIncluded	Did the analysis include all the relevant GMO crops?
AllIngredientsIncluded	Are all ingredients, listed on the product label, included in the analysis?
OmnipresentGMOsIncluded	Are omnipresent GMO varieties included in the analysis?
NumberScreenElem	Number of screening elements
ReliabilityForUnapprovedGMO	Reliability of applied methods to detect unapproved GMOs
NumberScreenElem	Number of screening elements
AppropriateDataAnalysis	Application of appropriate data analysis methods
AppliedQualitySystem	Can we trust the applied methods and analytical lab?
ValidatedMethods	Application of validated analytical methods
AccreditedLab	Is analytical laboratory acredited?

Figure 1. Hierarchical structure of the SIGMO multi-attribute model

The SIGMO model, as given in Figure 1, is implemented in DEXi software package [8]. To assess the likelihood of GMO presence in a product, the model is at the highest level decomposed into two main subtrees:

- *TraceabilityData* – data that accompanies each product and describes its geographical origin and path in the production/supply chain [9], and
- *AnayticalData* – provide information about the approved and/or unapproved GMOs already detected in the product, and about the methods used to analyze the products for GMO content [10, 11].

Usually analytical data are rarely available with a product, but if they are available, they are potentially more relevant for assessing the possible presence of (unauthorized) GMOs than traceability data and should thus take precedence.

A more detailed description of attributes and utility functions of the model are given in [6].

2.3 SIGMO user interface

When using SIGMO (http://decathlon.ijs.si/gmo/), the user is presented with an interactive input form, such as the one presented in **Figure 2**, in which the user enters data about the product to be assessed. The system provides guidance through drop-down data-entry lists and info buttons on the right hand side of each data-entry field.

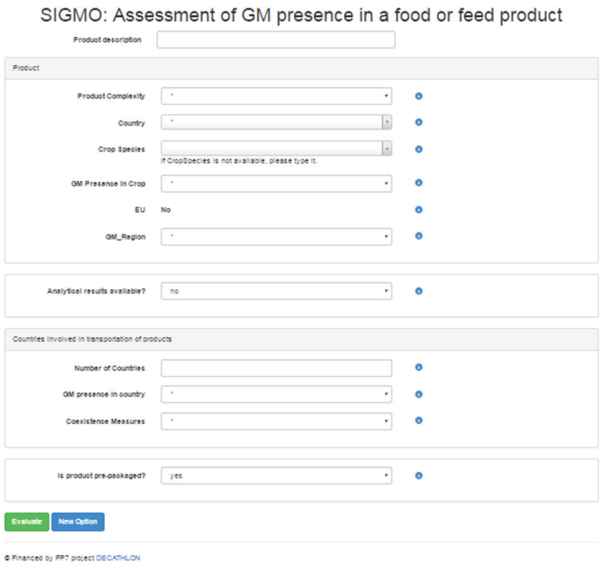

Figure 2. SIGMO user interface

Additionally, some parts of the input form are optional and open up only when necessary. Such examples are:

- only when *Product Complexity* is "complex", more than one ingredient can be entered;
- when *Analytical results available* is "yes", further detail about analytical results are requested;

- for products that are not pre-packaged, further data for transportation is requested;

After the data has been entered, pressing the button "Evaluate" shows the output page that displays the results of assessment. These results can be further explored by "drilling down" the evaluation tree.

SIGMO also provides a print page, which is suitable for saving and printing the evaluation results, and a help page describing the meaning of input data fields.

The system's architecture was designed by employing concepts that will allow seamless scalability. In that manner, the system is depends on MongoBD and MySql. The application is Django web application that runs on Apache through mod_wgsi. As such the application can be easily scaled in order to accommodate substantial traffic increase.

3. USAGE OF THE SIGMO DSS

Here we present several examples of how to use the SIGMO DSS in order to answer important GMO related questions about imported feed and food products.

3.1 Example 1

In the first example we answer the following question: given the origin of a certain product that consists of only one ingredient (for example popcorn), can one find all crops that may contain genetic modifications? To answer this question we consider a product that is made of crops, and that originates from Indonesia. Running SIGMO and checking the *Crop Species* field, we get the list of all crops that are produced in Indonesia and which potentially may contain unauthorized gene modifications in EU. The list contains *Maize, Soybean* and *Sugarcane*.

3.2 Example 2

Another relevant question when importing products from outside the EU is whether the country of origin has large fields that are populated with certain GMOs thus providing higher possibility for importing them in EU. For example, using the SIGMO model, one may be interested whether or not *Cream Style Corn* canned product (see **Error! Reference source not found.**) that contains *maize* and is produced in *Thailand,* is produced in a region of large GMO production. By selecting the appropriate values for *Country* and *Crop Species*, SIGMO provides the result *no*.

Figure 3. Cream Style Corn product from Thailand. Available from https://www.alibaba.com/product-detail/Cream-Style-Corn_131818000.html

3.3 Example 3

In this example we consider products that are made of several ingredients, each of which may have different probability of GMO presence. For example, one may be tempted to buy pasta made form *maize* and *rice* that are produced in Philippines. To assess the probability of presence of GMOs, we use SIGMO to evaluate both ingredients separately regarding the possibility of GMOs. As a final result, SIGMO aggregates the outputs of the evaluations into one recommended answer. For the provided example, SIGMO evaluates the possibility of unauthorized genes in the selected products as high. However, SIGMO also considers other attributes. Considering the fact that the product is packed, the possibility of commingling with other *maize* or *rice* is none. Therefore, the system evaluates the risk of GMOs in the product as *medium* to *low*.

3.4 Example 4

Consider that one wants to find out the GMO presence in complex products consisting from *rice* and *papaya* produced in China. The product is *packed*, and comes with a documentation from which the user may see that the product provides *Analytical results* from a laboratory. The results show that no *Approved* or *Unapproved GMOs* were identified by the laboratory. Hence a new drop-down menu is shown that asks questions regarding the laboratory results. The user answers as follows: "yes" for *GM presence in country* , "moderate" for *Processing Level*, "yes" for *Appropriate Sampling*, "yes" for *All Ingredients Included*, "yes" for *Omnipresent GMOs Included*, "many" for *Number of Screening Elements*, "yes" for *Appropriate Data Analysis*, "yes" for *Validated Methods*, "yes" for Accredited Lab. The next question is *Is product pre-packed* to which the user says "no". Hence, the user is asked a new set of question about the product transportation. The answers are "few" for *Number of interactions*, "no" for *Harbour*, and "no" for *Silo*.

Given these data, SIGMO provides information on *a-priori* GM presence in the product which is "high" for rice and "med" for papaya. Still, SIGMO's final assessment of GMO likelihood is *v_low*. The rationale is that the product has been inspected by a laboratory that did not find any authorized or unauthorized GMOs, and all additional questions regarding the laboratory indicate that the product has been properly inspected. Although the product has not been packaged, it also has neither been stored in silos nor had other interactions with other products at harbors. Thus, the final recommendation from SIGMO is that there is a very low probability that the product contains GMOs.

3.5 Usage of SIGMO

So far, SIGMO has been presented twice during the Decathlon project to project participants, traders, producers and importers: once in Lisbon, Portugal in 2015, and once in Shanghai, China in 2016. To measure the impact and usage of the system we have anonymously collected the country of accession of the SIGMO's web page. A histogram of different accesses to SIGMO in the

period of 15.1. – 15.7.2016 is given in Figure 4. From the histogram we can see that although the system has been presented only to participants from involved project countries (http://www.decathlon-project.eu/article/consortium), SIGMO has been used worldwide. Additionally, we present the monthly distributions of web-accesses of SIGMO in the period from December 2015 to September 2016 in Figure 5. The histogram shows increases of web-access from less than 100 in December, 2015 to more than 800 in July, 2016.

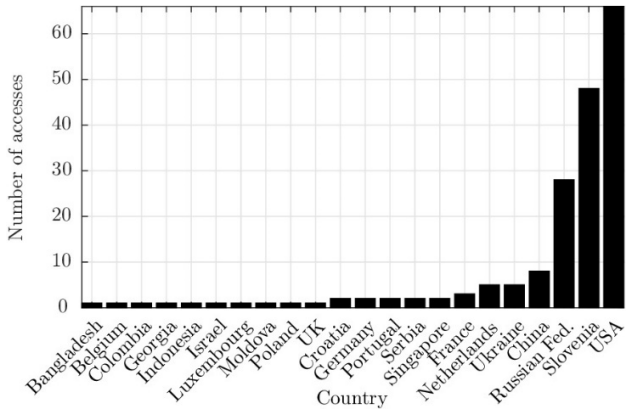

Figure 4. Different accesses points to SIGMO in the period of January, 2015 to July, 2016

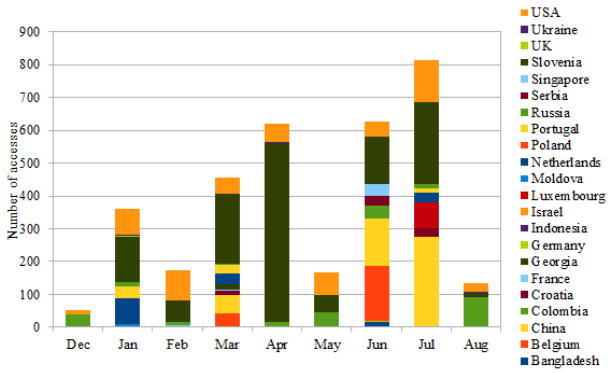

Figure 5. Distribution of SIGMO web-site visits per month in the period from December, 2015 to August 2016

4. CONCLUSION

The main goal of SIGMO is to help traders, producers and importers to assess the probability of existence of (un)authorized GMOs in the feed and food products. Here we presented four examples of how to use the system to achieve its goal. In addition we presented the number of accesses to the system in a six month period. Although the system has been presented only in Portugal and in China, it has been accessed from 22 countries. The presented examples can be used in future also for demonstration purposes to students studying for example decision sciences, in particular the DEX methodology.

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6. REFERENCES

[1] European Food Safety Authority. 2016. http://www.efsa.europa.eu/.

[2] European Commission Fact Sheet. 2015. Questions and Answers on EU's policies on GMOs Press release Database," http://europa.eu/rapid/press-release_MEMO-15-4778_en.htm.

[3] European Commission. 2016. Genetically Modified Organisams. EU register of authorised GMOs. http://ec.europa.eu/food/dyna/gm_register/index_en.cfm.

[4] European Commission. 2016. RASFF - Food and Feed Safety Alerts. http://ec.europa.eu/food/safety/rasff/index_en.htm.

[5] European Commission. 2003. Regulation (EC) No 1829/2003 of the European parliament and of the council of 22 September 2003 on genetically modified food and feed. *Official Journal of the European Union, L268,* 1 - 23.

[6] M. Bohanec, B. M. Boshkoska, T. W. Prins and E. J. Kok. 2016. SIGMO: A decision support System for Identification of genetically modified food or feed products. *Food Control,* 168–177.

[7] M. Bohanec, V. Rajkovič, I. Bratko, B. Zupan and M. Žnidaršič. 2013. DEX methodology: Three decades of qualitative multi-attribute modelling. *Informatica,* 49 - 54.

[8] M. Bohanec. 2015. DEXi: Program for multi-attribute decision making, User's manual, version 5.00. Ljubljana: Jožef Stefan Institute. IJS Report DP-11897. Ljubljana.

[9] European Commission. 2013. Regulation No. 1830/2003 concerning the traceability and labelling of genetically modified organisms and the traceability of food and feed products produced from genetically modified organisms and amending Directive 2001/18/EC.

[10] A. Holst Jensen, 2009. Testing for genetically modified organisms (GMOs): Past,present and future perspectives. *Biotechnology Advances,* 27, 71 - 1082.

[11] A. J.Arulandhu, J. P. V. Dijk, D. Dobnik, A. Holst-Jensen, J. Shi and J. Zel. 2016. Critical review: DNA enrichment approaches to identify unauthorised genetically modified organisms (GMOs). *Analytical and Bioanalytical Chemistry*.