On Intelligent Sensors and Internet of Things Based Cyber-Physical System for Consumer Protection

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Abstract - The new approach to consumer protection problems is represented by various mathematical, physicochemical, virtual and fractal modelling methods based on a cyber-physical platform, as well as original intelligent quality control tools for consumer protection. The existing consumer protection system is outdated and does not meet new challenges in the booming digital world of smart technology, as its work ignores individual requirements, local opportunities and regional features. The obtained results demonstrate that the developed compliance control algorithms, intelligent tools, and mobile applications based on the cyber-physical platform used in the analysis of some agricultural products allow to carry out the process of time return and fully reproduce the adjusted biological, physicochemical parameters and processes that occurred in the past. The obtained results provide a dialectical ascent from abstract information to operational knowledge. On the basis of the results of experimental research and modelling of "intellect of consumer" was developed new conformity assessment method, based on the principle of fractal similarity of metrical images. As a whole, the results of research more fully contribute to the protection of the interests and rights of consumers in accordance with the United Nations Universal Declaration about human rights to a safe existence.

Keywords: Artificial Intelligence, Consumer Protection, Cyber-Physical Systems, Internet of Things

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1. Introduction

1.1. The paradigm of Food Safety

Currently, the emphasis of the computing industry is gradually shifting towards AI, which is becoming the centrepiece of creating new value not only for business and management but also for protecting consumer interests. This situation creates the need to draw a clear line between hardware and software to adapt technological and computing capabilities to various data processing and integration requirements in *IoT-CPS* and *Android App* [1-4, 12-15, 19-21].

However, it should be recognized that the possibilities of effective consumer protection and the problem of food security have not been sufficiently studied, as evidenced by the relatively small number of publications on this topic.

Some traditional approaches to solving a similar class of problems that were partially used in this work are described in detail in the scientific literature [2, 7-15, 19-22]. The main value of data obtained using IoT-CPS is their ability to accurately record local conditions and take into account the individual needs of consumers. But even publicly available data have limitations, uncertainties and potential unobserved deviations (for example, due to flawed surveillance procedures and primitive testing devices). Regional models of food security and consumer protection are better in the interests of consumers by analysing additional local variables arising from the provision of consumer services and goods in a smaller area.

The global approach to consumer protection often underestimates factors of regional and local uncertainty. But in modern conditions of digitalization, this is not enough to create effective consumer protection structures. As a result, the number of government consumer protection centres in Latvia is reduced and the consumer is often forced self to defend his own rights.

Consumers should understand that supervisory authorities will never be able to fully solve the problems of protecting the rights and interests simultaneously of the state, manufacturers and consumers because in conditions of unfair market competition they often not only do not coincide but also diametrically opposite (Fig.1).

The concept of the sphere of consumer interests includes both general human rights and legal, economic, social and other aspects of the problem. The existing regulations and instruments as a whole can serve as a legislative framework to ensure common approaches and principles of the European Economic Community.

These requirements in democratic countries are considered absolute, unquestionable and inviolable. Each product and its production technology must comply with the relevant rules, which are regulated by internal and international documents. EU directives provide for a provision that each country should have its own quality and conformity control system, consistent only in general principles and approaches with the international system [17-18].

Fig. 1 shows the triad of the food safety paradigm, reflecting the main functional ties between the rights and interests of the state, producers and consumers.

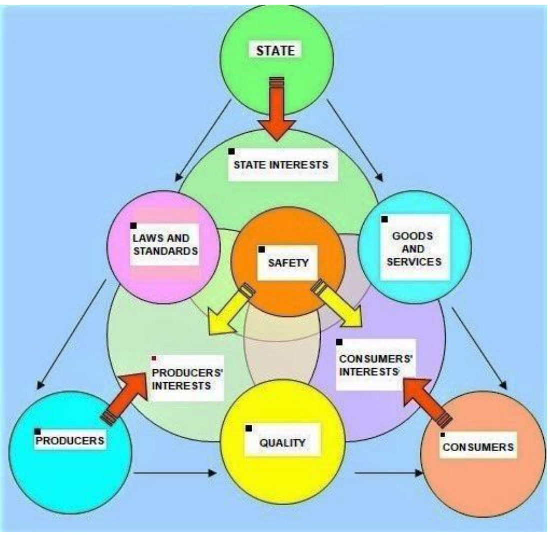


Fig. 1 Paradigm of Food Safety

As can be seen from the scheme we proposed, the most vulnerable and least protected link of this triad is consumer rights and interests. Therefore, in the context of a conflict of interest, there can be no question of any stability of the food safety system.

1.2. The paradigm of AI for consumer protection

If we set the task wider, the paths of a human being and a computer differ sharply in accordance with the principles of functioning. The machine that executes the algorithm, with relative ease, calculates at least half a million images and has enough computing power. But human beings can immediately and simply determine the emotion of the face without any theoretical models and mathematical calculations: for example, evil, excited, calm, attractive or repulsive faces. At the same time our brain is sharpened not for the brute force of knowledge, but for associative comparison, that is, using an incompletely defined standard and not complete previous knowledge. Therefore an approach, based on the assessment of the conformity and recognition of the generalized geometric image of the standard product quality, greatly simplifies the data processing procedure. Today it is hardly possible to recognize artificial intelligence as equal to humans. AI today is only a fast computing machine that uses the learning algorithms embedded in it to solve specific problems, Fig.2.

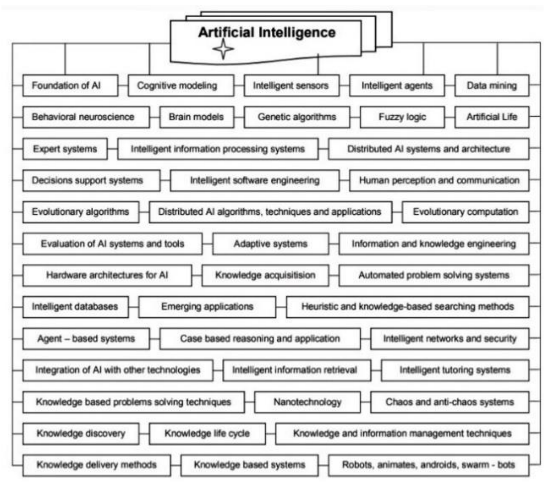


Fig. 2. The paradigm of artificial intelligence

This is a complex information system, but it solves problems based on algorithms developed by man, without going beyond the framework indicated by specialists in advance. The task of creating intelligence that is truly comparable to humans is on the agenda. Today, we use artificial intelligence in areas where human beings are not working in the best way. It has not yet been possible to create a competitor to the human mind in all its manifestations.

The computer performs sequential computational operations at speeds that are crazy by human standards. He is designed to implement algorithms and solves this problem brilliantly. A human being is not initially adapted to perform algorithms. We don't know how to compute quickly. Our brains are adapted only for a single operation - finding associative connections.

A human being solves any task by selecting suitable associations. And it does it incommensurably better than any computer. An example is visual facial recognition or recognition of any other images. Indeed, this problem is now solved by a human being and a machine at approximately the same level of success. True, they both do it in completely different ways.

The computer - calculates the characteristic points and calculates the correlation, and the human being - searches the memory for associations of characteristic points and establishes connections between them. While it's about the private question of "determine what it is?" both approaches produce roughly equivalent results.

In Fig.2 the main scientific research directions in the field of artificial intelligence have been reflected.

2. Problem Formulation

The traditional methods of food safety control based on the application of different types of sensors and combinations of them in the analysis of food and agricultural products are expensive and difficult to use by the consumer. For example, the application of data from visual images, spectral, ultrasonic and dielectric characteristics, in combination with the selected classifiers and prediction models in the systems for quality assessment of food and agricultural products in the fact is a complete scientific laboratory, therefore consumers cannot use such methods and instruments in everyday life practice [14-22]. To make it easier for consumers to take advantage of digital *IoT-CPS*, the challenge is to develop a technology that is user-friendly and focused on obtaining specific knowledge rather than abstract information.

According to European legislation [17-18], for ensuring the safety of products placed on the market are responsible food producers. Foods are safe when quality raw materials and technologies are used in their production and by applying systematic control and management. At the same time, the consumer, using compact intelligent tools, must promptly record not the absolute values of the physicochemical parameters of the product, but the presence of deviations from the norm and standard conditions, which eliminates the need for additional use of stationary and mobile laboratories.

Another problem is that today artificial intelligence is used in areas where a person does not work in the best way. The scientific work attempts to significantly increase the effectiveness of consumer protection by introducing an intelligent product quality control system at the national level using elements of artificial intelligence and sensors that simulate "consumer intelligence". Today, it is difficult to find a universal approach that is based on the implementation of the internet of things on the cyber-physical platform using such sensors, which would be communicating with mobile apps and with various mathematical, physicochemical and virtual modelling software for an elaboration a standard metric image. Problematic also is to create such original tools to ensure that consumers can independently self to evaluate the quality and safety of products.

It is also problematic to develop such reliable methods and tools for agricultural products that could be used in bionic stochastic processes with incomplete data, not fully systematized parameters and partially formalized requirements. The next problem is to develop algorithms and compact smart devices "artificial tongue" which provide a dialectical ascent from abstract information about product quality to concrete knowledge and more fully contribute to protecting consumers' rights to a safe existence [16].

3. Problem Solution

3.2. Methods and Instruments

In the research experiment, various statistical methods were used to create a virtual library of standard images to identify the deviations of the tested product from relevant metric images of the product (Moskvin et al., 2006). As the preliminary step of identification, the physic-metrical models of a tested product can be interpreted by using mathematical and statistical models [5-7, 11-13, 22-24, 30]

A wide analysis of the scientific literature has shown that for the purpose of creating IoT-CPS to protect consumers, the use of known methods of product quality control is impossible since mainly known methods are concepts of the previous generation that are incompatible with digital technologies [1-2,8-15,22] In addition, these methods are implemented by too cumbersome, difficult to operate and expensive device designs that, due to their large mass and size, are unsuitable for the personal protection of consumers. The results of our studies largely eliminate the listed shortcomings.

For the elaboration *IoT-CPS* platform, the applied sensing methods were applicated using intelligent sensors and “Artificial Tongue” (AT) - an electronic instrument, which consists of data acquisition, calculation and data analysing processors. For quality control against reference “good product" modelling the SIMCA method, as well as the partial least square (PLS) method, has been applicated.

Partially there was used cross transference of notions of chemistry, physics, concepts, techniques, and approaches between analogous agricultural products. The methodology of the research for the recognition of unknown samples includes the fundamentals of artificial neural networks *(ANN*), the discrimination and identification discrimination factorial analysis *(DFA)* method, as well as the principles of the commonly used template, recognition algorithms and classification methods such as *ANN, DFA, SIMCA, PCA, SVM, PLS and CNN,* which are presented in detail in the scientific literature [9-15, 22].

Artificial tongue *"Logicor -AT"* can be used to analyse one particular fruit and vegetables too item and can be adapted for other agricultural products, food items or components. This does not just mean the re-deploying of the specific *IoT-CPS* platform but also the application of other specific methods of bioinformatics and statistical analysis [5-6, 8-9, 30-33]. Preliminary identification of quality parameter deviations in tested products was detected and interpreted by means using mathematical, physicochemical and statistical models.

Analysis of significant changes in the field of information technology, especially respecting for total digitalisation in all spheres of business and control, as well as the presence of problems in the field of consumer protection, shows the need to search for new ideas and new opportunities for consumer protection through the use of *IoT* technologies on a cyber-physical platform [1-6, 18-23].

The use of intelligent sensors, the original device "artificial tongue", microcontroller and fractals based on self-similarity quasifractal geometric models allows for analysing, return in time, and accurately reproducing corrected biological, and physicochemical parameters of processes that occurred in the past. This statement rightly applies not only to biological objects and processes but also to living and non-living matter at all. To better understand the methodology for solving the problem, a metric image paradigm was developed, reflecting the physicochemical parameters of the product under study using a new intelligent tool "artificial tongue".

3.2. Fundamentals of back transformation algorithms (BTA)

In the mid-70s G. A. Moskvin (Latvia University of Life Sciences) in connection with the development of automated microprocessor control systems and the creation of intelligent measuring and dosing devices in agriculture, Fig. 4, [24-29]. Then in the 80s, P.J. Werbos, B.E. Rumelhart and D. Parker developed their options for applying back transformation algorithms [23]. In 1986, Rumelhart B.E., Minton G.E., Williams R.J. and Jeffery E. Hinton demonstrated the ability of algorithms to train hidden elements and produce representations for complex patterns at the entrance. In the 70s many instrumentations based on *BTA* successfully worked at the world's first fully automatic dairy farm with rotary-conveyor technology in Koknese, Latvia. *BTA* is an effective algorithm for calculating and correcting optimal *ANN* weights, as well as for recognizing metrical patterns and improving various physicochemical, statistical and metrological characteristics [1, 7, 24-29]. Fig. 4 shows the first international patented smart devices that were developed on the basis of *BTA* (Gold Medal of the PALEXPO International Exhibition, Geneva).

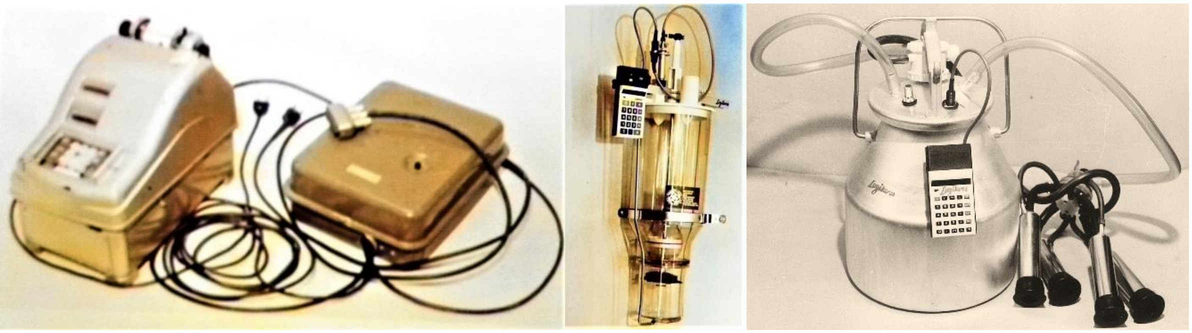


Fig. 4. Historically, the first international patented smart devices were developed on the basis of BTA

3.3. Cyber-Physical System for consumer protection

Consumer protection systems are currently being developed and updated. Apps on mobile smartphones can be used to obtain operative information about the properties of products, hazards for health, producers, traceability of goods, etc. The IoT-CPS concept for consumers' protection easy adapts to the technological and computing capabilities of Android apps. According to EU legislation, the main tool to ensure the enabling swift reaction when risks to public health are detected in the food chain is R*ASFF* – the Rapid Alert System for Food and Feed [17-18].

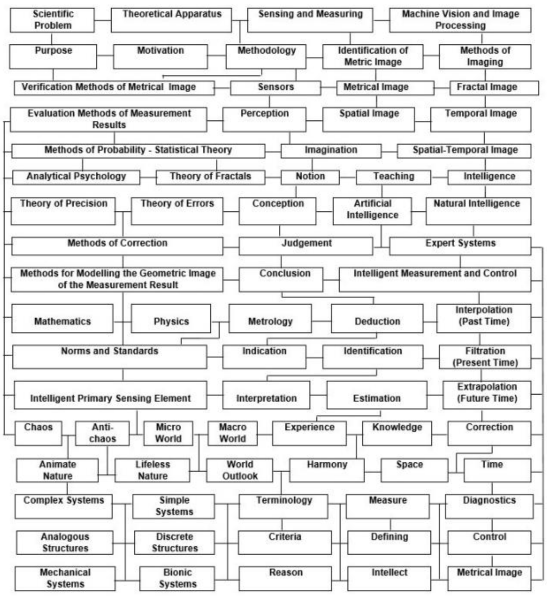


Fig. 5. The paradigm of metrical image

Cyber-Physical Systems *(CPS)* allow you to form the measurement process on a deeper intellectual basis, dividing the measurement process into the following component elements of the cognitive matrix: sensation, perception, imagination, concept, judgment and conclusion. The steps of ascending abstract information to a specific image recognition result should be supported by *AI* elements using *"VortexPro"* algorithm built on the basis of the paradigm of metric image (Fig. 5). Elaborated algorithms of *"VortexPro"* provide a dialectical ascent from abstract information to specific knowledge.

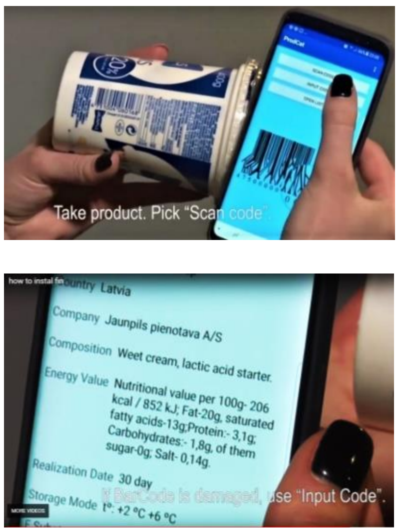


Fig. 6. IoT-CPS mobile apps ProdCat for consumers' protection

In this work, we offer one of the new possible concepts of consumer protection based on the using artificial tongue, *IoT-CPS* and quasifractal images of conformity. Consumer knowledge-based approach to main trends analysing gives a clear perspective on the genesis and characteristics of global changes in the area of consumer protection using *IoT-CPS* technologies and smart sensors. Some cases for consumers' protection can be successfully used mobile apps and smartphones. For example, *ProdCat*, together with the Latvian University of Life Sciences, has created consumer guides in Latvia to help learn more about hidden health hazards in everyday products [3-4], (Fig.6). Recently, various concepts of intelligent quality control sensors, such as artificial noses and languages, have been used in the food industry and in agriculture to control the quality of agricultural products [9-16]. But they are expensive and complex in practical application. In addition, they require the services of specialists with specific skills and preliminary knowledge. Fig. 7-8 shows a compact, user-friendly and relatively inexpensive concept for consumer protection using the *Logicor-AT* artificial language on the *IoT-CPS* platform. A positive feature of the proposed concept is the development of a library of metric images using an advanced classification and correction algorithm.

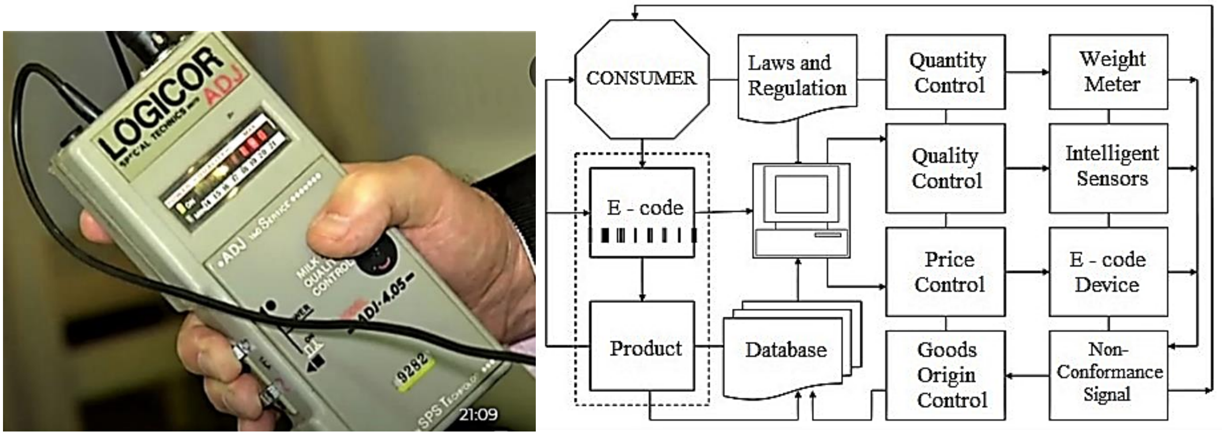


Fig.7. Concept of compact artificial tongue "Logicor-AT" for consumer protection on the IoT-CPS platform

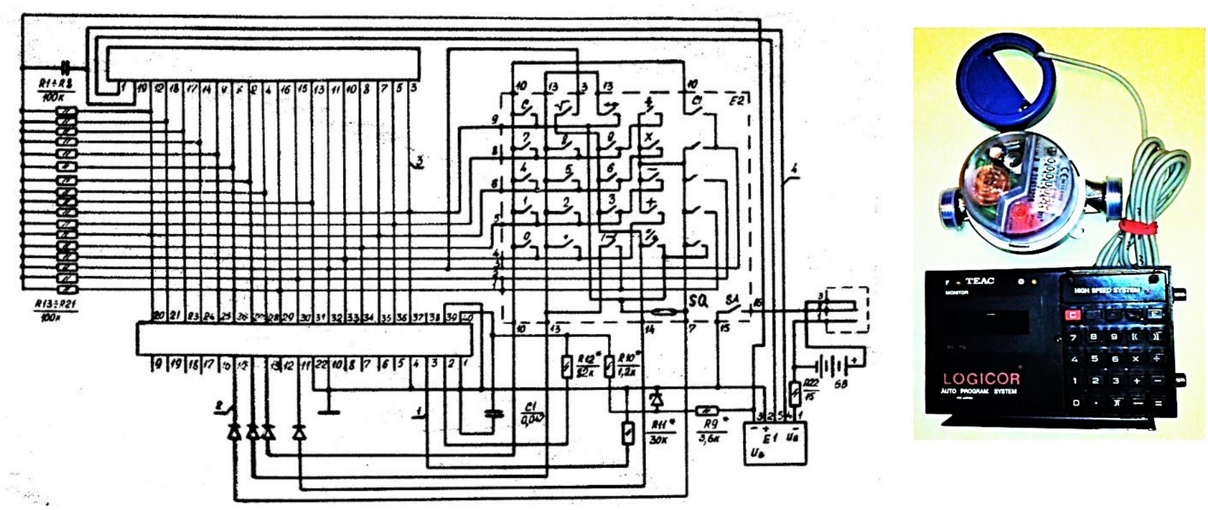


Fig. 8. BTA "Logicor-AT" device for calculation of an optimal ANN weighting factor Kid for IoT-CPS

3.4 "Chernoff' Faces" perceptual recognition method

Herman Chernoff proposed simplified face shapes to represent a number of variables in a data set, by mapping numbers to the size and curvature of the face, the position of the eyes, length of the nose, position of the mouth, etc. These faces are a type of glyph, a graphical object whose properties represent data values.

The results of measuring the same product, which is fixed by different devices, can be so significantly different that they often do not reflect any physical essence or knowledge. The advantage of *IoT-CPS* for the protection of consumers is that instead of a set of crude information, complex knowledge is used. The development of the modern consumer protection paradigm on the *IoT-CPS* platform needs its special own research methodology and special instruments using intelligent sensors and mobile applications.

Virtual "standard metric images" for a library of cyber-physical systems *(CPS)* can be created based on the *"Chernoff' Faces"* recognition method [30-33], as a human being can quickly and intuitively recognize the faces without any data processing. The goal of "faces" geometrical image processing is the detection of not correct parameters of "faces" and to locate and identify deviations from the parameters of "standard faces". Physical parameters of the "face" are interpreted as geometrical and are compared with the standard form of nose, ears, eyes, hair, eyebrows, mouth, oval of the face, etc. The deviations of any virtual parameters of "faces" from the norm are correlated with the deviations of real physical parameters of "the standard face". The goal of "face" recognition is to virtually identify the quality of a product based on the image of its real „face". This "face" image has to be compared with the registered "standard faces" of products, (Fig.9).

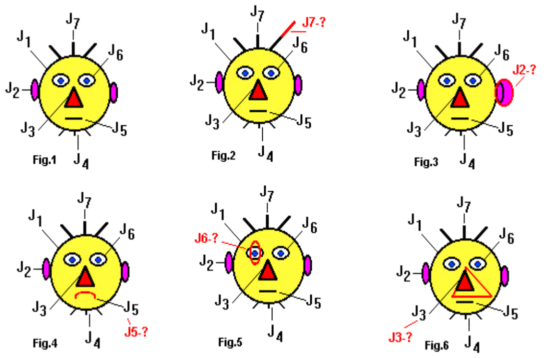
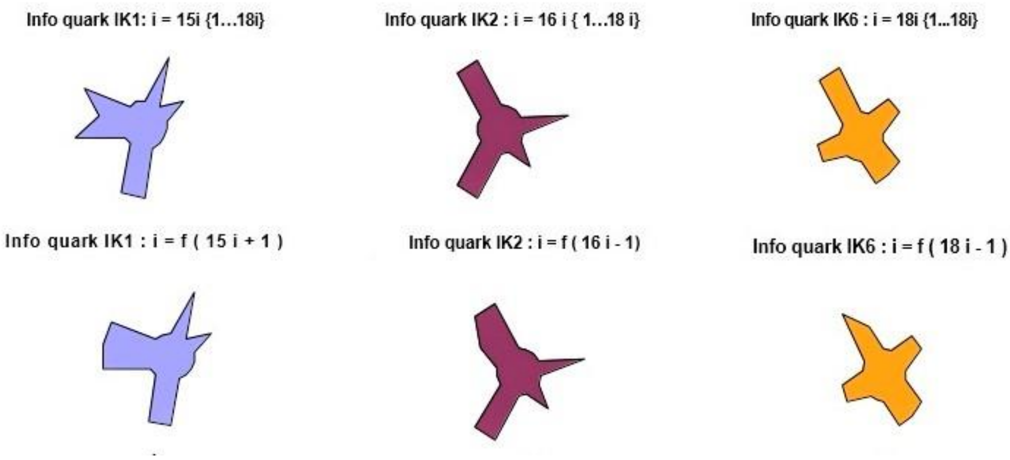


Fig. 9. "Chernoff Faces" recognition method, where J1- J7 are the physic-chemical parameters of the tested product (Fig.1 –"standard" face)

4. Results and Discussion

It is clear that the perceptual "standard" of Chernoff's faces is approximate. Here we are dealing not with numbers, not with abstract information, but with concrete knowledge about the correspondence or inconsistency (yes-no) of the recognized image with the presented model. Each geometrical parameters of the Chernoff's faces represent some data value. In Fig. 10 perceptual image recognition method using "info-quarks" is shown.



a **b** **c**

Fig. 10. Recognition of metrical images by using "info-quarks", where **a, b,** and **c -** is the physicochemical parameters of three different tested products

Our research focused mainly on the development of classification algorithms. The sensor system for forming metric images consists of a set of sensors and a proprietary device "artificial tongue". Measurements for creating a library of metric images of *IoT-CPS* were carried out on the basis of unified mathematical, physical, metrological and fractal images with the subsequent automatic identification of product quality compliance. The experiments showed that the control of the compliance of agricultural products with sufficient accuracy (88%-93%) can be carried out using a simple and intelligent artificial language sensor (*AT*) on the *IoT-CPS* platform, Fig. 11-19

Checking the compliance of the tested samples with the required product quality can be carried out by perceptual determination of deviations by comparing samples of "standard" quality and the actual metric fractal of the tested product using an artificial tongue on the IoT-CPS platform. Table 1 shows an example of determining the optimal weight factor (K_{ind}).

Table1. Example of determining the optimal *ANN* weighting factor (K_{ind}) for *IoT-CPS*

F = 7.0 kHz	F = 7.0 kHz	F = 7.0 kHz	F = 7.0 kHz	F= 7,0 kHz	F = 7,0 kHz	F = 7,0 kHz
A = 1,0 dB	A = 1,0 dB	A = 1,0 dB	A = 1,0 dB	A = 5,0 dB	A = 5,0 dB	A = 5,0 dB
dW = 0	dW = 10ml	dW = 25ml	dW = 35ml	dW = 50ml	dW = 100ml	dW = 100ml
8	6,8	2,1	2,2	2,4	2,2	2,2
K id	K id	K id	K id	K id	K id	K id
As=1 dB	As=1 dB	As=1 dB	As=1 dB	As=5 dB	As=5 dB	As=5 dB

As a result of scientific work, it is proposed to significantly increase the efficiency of consumer protection by using artificial intelligence and smart sensors that imitate the intellect of consumers. The intellect of consumer functions is based on the *IoT-CPS* platform, mobile applications, personal microcomputers and smart sensors. The main feature of the developed technology friendly to the consumer is the participation of sensors and computational intelligence in the receipt, transmission, processing and perceptual presentation of the deviations determining product quality. Fig.6 shows, as an example, the determination of the optimal weighting factor using a buffer sample with distilled water (dW) on the basis function $K_{ind} = f$ (dW).

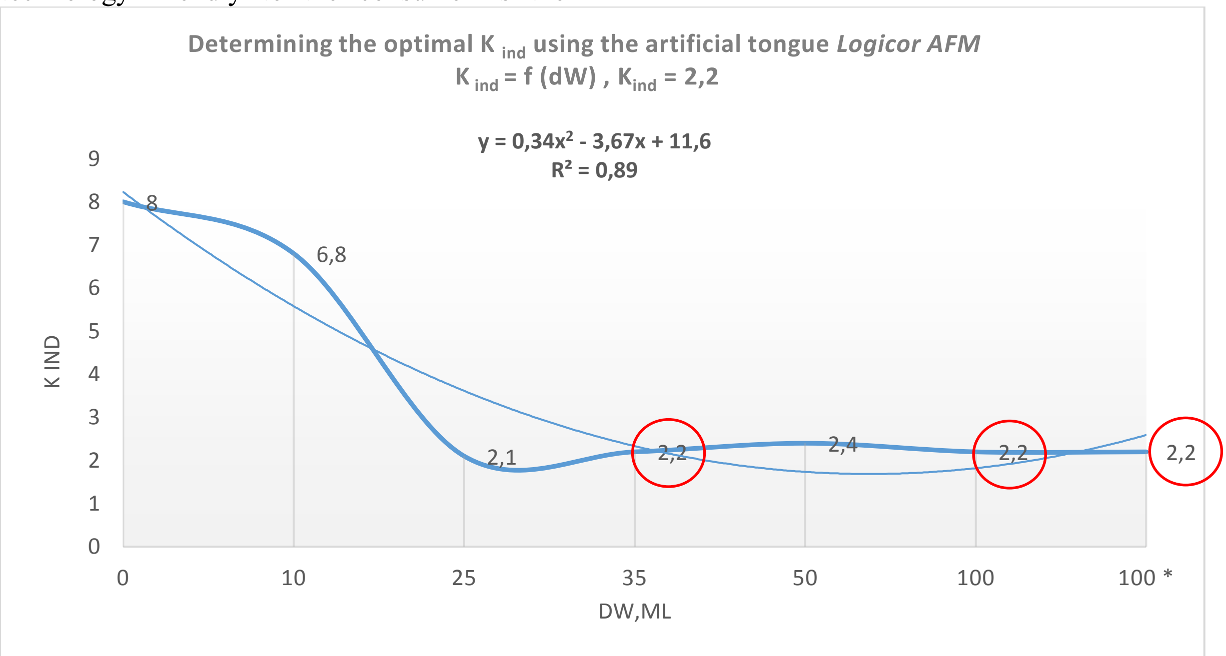


Fig.11. Determining an optimal *ANN* weighting factor on the basis function $K_{ind} = f$ (dW)

The biggest problem related to the application of *BTA* is that an *ANN* requires the teacher to provide the desired result for each example of training. But firstly, in a natural environment, a person is able to learn without the help of a teacher. Secondly, no one gives us in advance a detailed description of the picture of the world and the ready for using ideal global ideas, from which we could learn to benefit by means of using our own, local touch input. Thirdly, we learn to understand speech, visual scenes and visual images without any direct instructions, that is, we are still able to perceive ready-to-use knowledge directly, without the participation of any intellectual intermediaries at all. Fourthly, predictable deterministic systems operating according to ready-made algorithms with a previously known result do not have any intelligence at all - nor living or artificial, and therefore, cannot be ranked among the field of *AI* systems.

The time required to calculate the error derivatives by weights in each training example is proportional to the size of the network since the amount of computation is proportional to the number of weights. However, larger nets require more training examples and have to modify weights more times. Therefore, learning time is growing significantly faster than the size of the network. Despite the noted shortcomings, the use of *BTA* and *BPA* methods is very effective, since the degree of system uncertainty is reduced and therefore there are no situation uncertainties of actions to be taken with the information, coming to the input of individual neural networks or the system as a whole.

A simple form of visualization and presenting ready-to-use knowledge about the properties of the product is very convenient for the protection of consumers. In addition, the easy geometry images of the conformity created based on a cyber-physical platform contain the main fractality properties of tested products.

Therefore, an elaboration of the library of the standard geometric images automatically lets us recognize and compare different samples of the product being tested. This methodology gives the additional capabilities using intelligent sensors on the *IoT-CPS* platform. In Fig.12 an algorithm for parametric identification and perceptual recognition of tested products using artificial tongue *"Logicor-AFM"* is shown. The application of the developed algorithm *"VortexPro"* shows that when assessing the conformity degree of quality or damages to apples "Marigold", the accuracy of the algorithm reaches 87-93%.

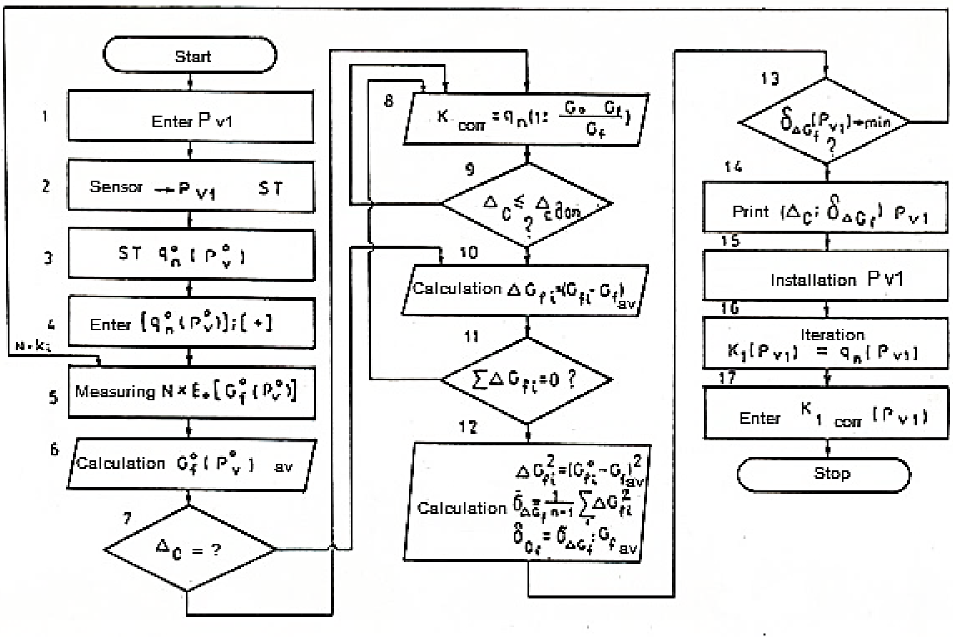
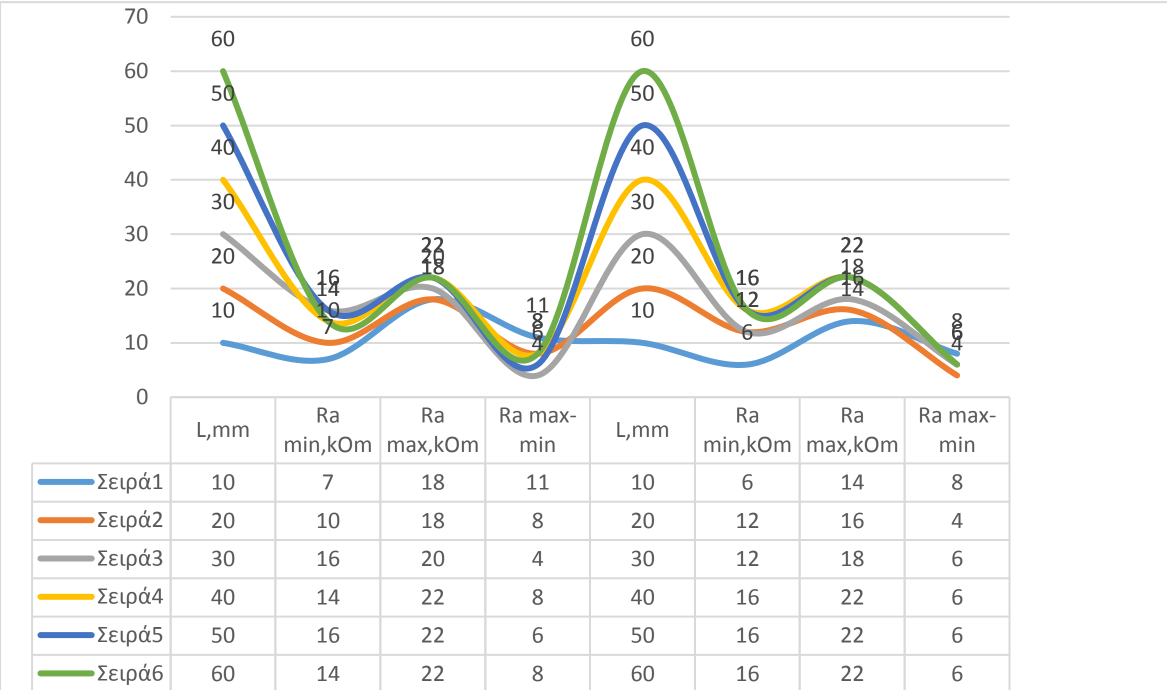


Fig.12. Algorithm for perceptual recognition of tested product using artificial tongue "Logicor-AFM"

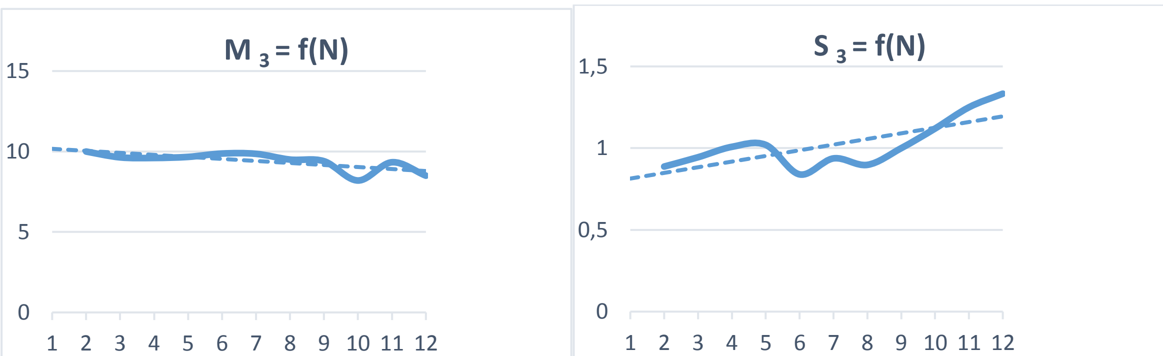
In the study, it was found that the ascent of abstractions of perceptual images in *AI* system occurs in a similar way to the work of *ANN*: from abstract sensations, perceptions, representations, concepts and judgments to specific conclusions. In accordance with this concept, the *VortexPro* processor works. *BTA* has proved surprisingly effective in training networks with multiple levels to solve a wide range of problems. They turned out to be the most effective in situations where the relationship between input and output is non-linear, and the amount of training data is quite large. The following Fig.13-14 shows the result of the apple "Marigold" test on the *IoT-CPS* platform.



	L,mm	Ra min,kOm	Ra max,kOm	Ra max-min	L,mm	Ra min,kOm	Ra max,kOm	Ra max-min
Σειρά1	10	7	18	11	10	6	14	8
Σειρά2	20	10	18	8	20	12	16	4
Σειρά3	30	16	20	4	30	12	18	6
Σειρά4	40	14	22	8	40	16	22	6
Σειρά5	50	16	22	6	50	16	22	6
Σειρά6	60	14	22	8	60	16	22	6

Fig. 13. Sample of test an apple "Marigold" using the analysing of local damages function Ra = f (L)

For the machine learning procedure, *IoT-CPS* must beforehand ask from database knowledge about the main physicochemical properties of agricultural products. Therefore for use of *IoT-CPS* technology, it is beforehand necessary to create a virtual library for the comparison of a "standard" metrical image with an actual physicochemical image of the tested product.



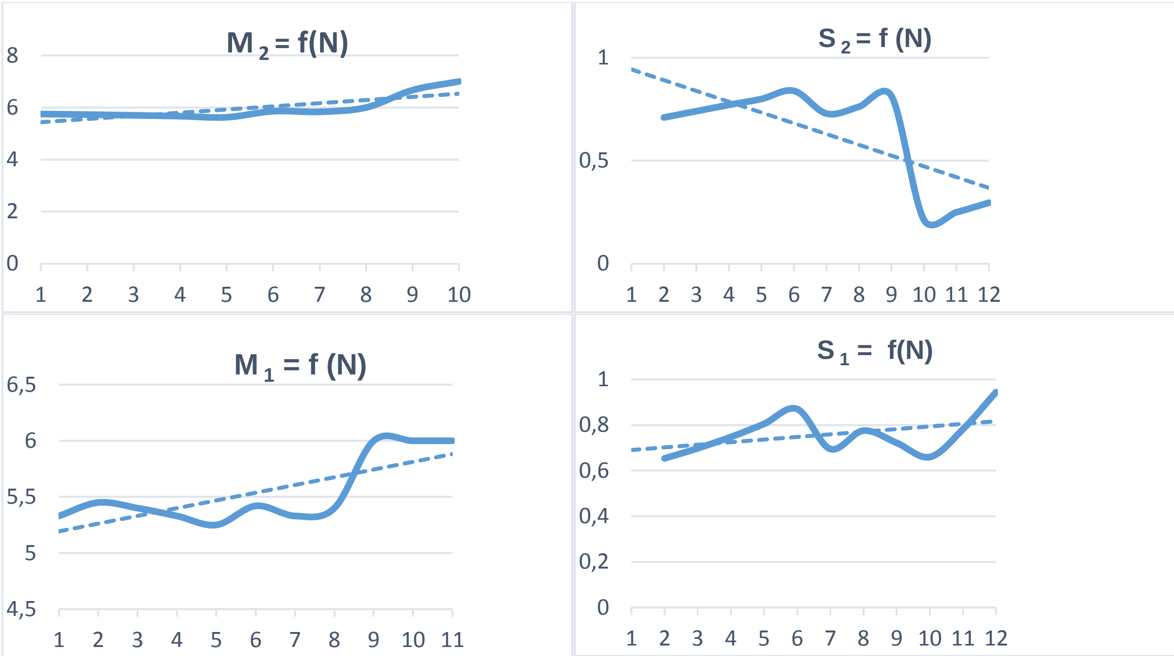


Fig. 14. Study of statistical characteristics the testing result of apple "Marigold" for the elaboration of the library of standard images

An experimental sensor system that forms a perceptual metric image includes an artificial tongue sensor, an electrical conductivity sensor, a dielectric constant sensor, a concentration sensor, a frequency sensor, an electronic chronometer for determining relaxation time - T_{rel}, penetrometer - L [mm], temperature sensor, ultrasonic sensor, electrical resistance sensor Ra and artificial tongue device, which is a device for verification of the standard metric image. (Fig. 15-16). Detailed work with these parameters and sensors is described in the review literature [9-15, 22].

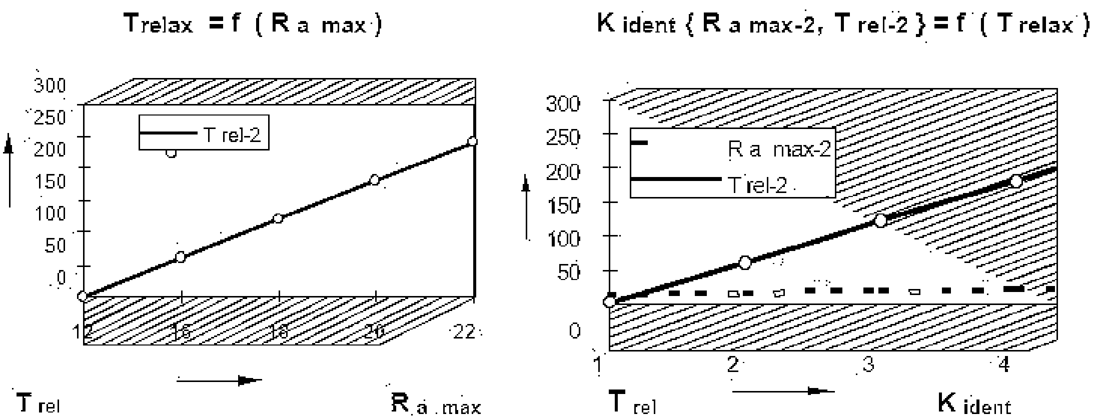
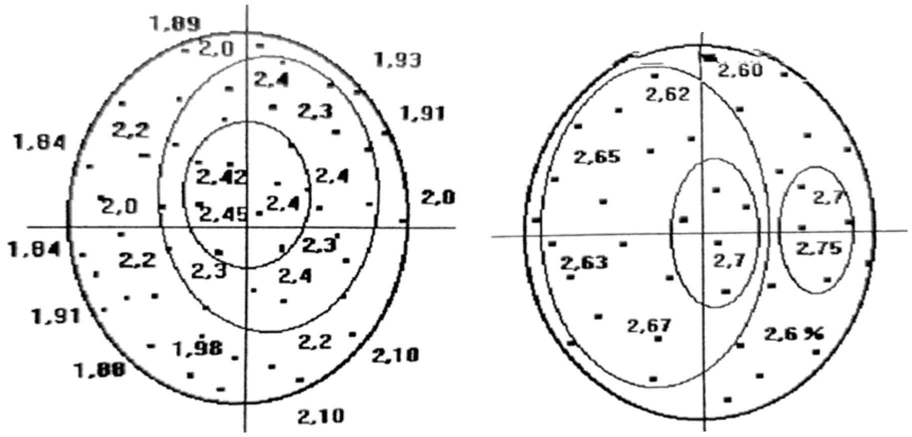


Figure 15. Research of physicochemical quality characteristics of apple "Marigold" $T_{relax} = f(R_{a\,max})$ and K_{ident} $\{R_{a\,max-2}, T_{rel-2}\}$ for an elaboration of *IoT-CPS* metrical images



a **b**

Fig. 16. Metrical image for an apple "Marigold" № 34: test under actual damages conditions [%], test 4 (**a**) , area №1-1,84%-2,2%, №2-2,21%-2,40%, № 3- 2,41%-2,45% ; test 5 (**b**), area №1-2,6%, №2-2,62-2,67, №3-2,7, №4-2,7-2,75, f=5 kHz, A=0.5 dB, T=22°C

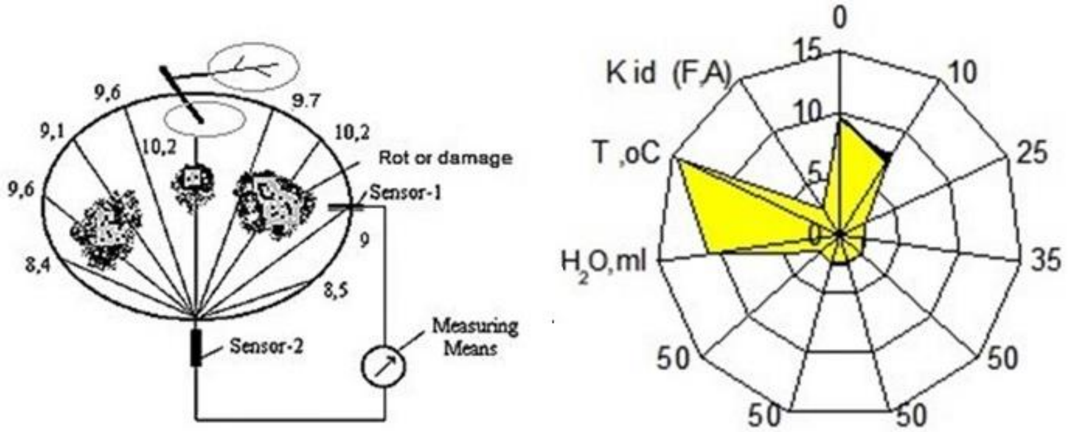
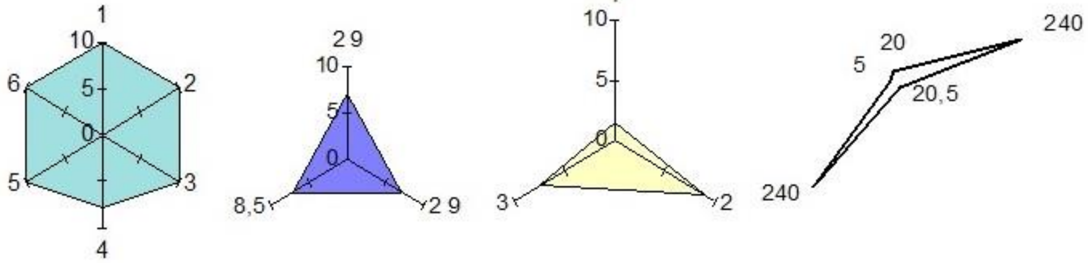
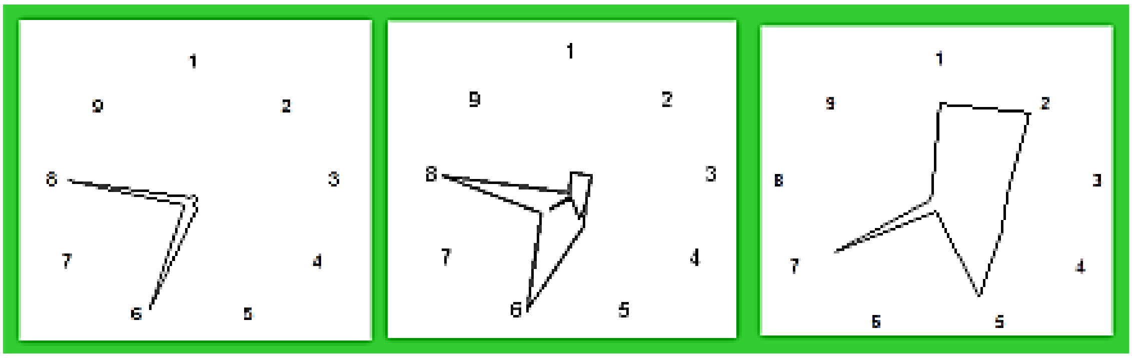


Fig. 17. Elaboration geometrical image for apple "Marigold"



a **b** **c** **d**

Fig. 18 Elaboration of fractal metrical images for a standard images library (SIL) using artificial tongue "Logicor AFM", where **a**- potato "Mutageni", **b** - potato "Sarmite", **c** – deviation from standard image "Sarmite", **d** – a metrical image of apple "Marigold".



a b c

Fig.19. Watch-fractals for classification of an apple “Marigold”, where a- 1.class (good), b-2.class (acceptable), c-3.class (bad)

The new *IoT-CPS* approaches are fundamentally complementary. In this work, we demonstrate that efforts of better understanding the possibilities of consumers’ protection would benefit from further close examination, and improved integration, of experimental data to alleviate model shortcomings - especially in real situations where primary data can vary markedly from real data. It is of utmost importance to design new generation conformity control methods and devices with the application of the fractal method, which can effectively work under changing peculiarities operation as well as to adapt themselves to the intellect of consumer's intellect and to bionic stochastic processes with an incomplete determination of study object in actual conditions.

Of course, *ANN* does not compete with the human brain. The problem is not at all how the system is trained, but the mystery of the original model of the device and the functioning of a living neuron. The *BTA* methodology has no analogues in wildlife, so the application of these methods today is not a universal means of solving all problems. Nevertheless, this is a fairly effective method of intellectualizing technology and a sufficiently reasonable additional tool for solving global consumer individual protection problems using intelligent sensors on the *IoT–CPS* platform.

4. Implications for future research

The direction of future research may be to study in more depth and in detail the possibilities of public policy in the field of consumer protection, to identify new approaches to stimulate the consideration of individual consumer needs, as well as the researches of new to find forms and ways to motivate individual entrepreneurs and firms to the more complete and unconditional compliance with consumer protection legislation. Global political and economic approaches cannot succeed, as local contexts and consumers' personal interests will always dominate. It is necessary to develop more detailed models of consumer protection based on the Cyber-Physical System platform and the Internet of Things that would take into account spontaneous business processes in a market economy and their current contexts.

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7. Conclusions

The main feature of the developed consumer-friendly IoT-CPS technology is the participation of intelligent sensors and computational intelligence in the reception, transmission, processing and ergonomic presentation of quality deviations in products. At the same time, the consumer, using visual comparison of real and standard fractals, immediately recognizes not absolute values of the physicochemical parameters of the product, but only deviations from norms and standards of quality.

Consumers are the main part of a social *IoT-CPS* network. This intelligent platform is a new business and consumer protection tool, which in the future will be used around the world by most industries.

Obtained results of the research has important for consumers' protection on the *IoT-CPS* platform using mobile applications and intelligent sensors as well as for the future development of local intelligent systems and technologies as a whole.

Elaborated new consumer-friendly technology is focused on obtaining not abstract information but specific knowledge. The advantage of the obtained results is the simplicity, reliability and economic effectiveness, which do not require high qualifications and the use of mobile laboratories.

The results of the research show that many tasks of identification and classification for consumer protection can be successfully solved by means of the algorithm *"VortexPro"* using intelligent sensors.

Today it is hardly possible to recognize artificial intelligence as equal to human intellect. AI today is only a fast computing machine that uses the learning algorithms embedded in it to solve specific problems. Intelligence and algorithm are incompatible.

The use of fractals as metric images based on self-similarity models in the *IoT-CPS* allows for analysing, return in time, correction and reproduction of biological, physical and chemical parameters and processes that occurred in the past. This statement rightly applies not only to technological objects and processes but also to living and non-living matter as a whole.

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