Improvement of traceability of widely-defined measurements in the field of humanities

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Abstract

Last decades, a tendency to extend a domain of measurements to the field of humanities characterized by fuzzy measurements of multiparametric measurands has been observed. In this process fuzzy measurement should meet the requirements of metrological traceability. In the paper, the proposed approach to the development of measurement model in the field of multiparametric measurands is grounded. The ground is given with an example of measurements of the emotions in music fragments. It rests on the results of statistically stable expert judgments as well as on the hypothesis proposed by the authors of this paper, which explains the formation of emotions in the evolutionary process.

Keywords: Traceability, multiparametric measurand, music perception

1. Introduction

In the field of humanities, the necessity to estimate multiparametric measurands in experiments often arises. Accordingly, last decades, a tendency to extend a domain of measurements (in a wide sense) performed with the help of measuring instruments, to the field of humanities can be observed. These measurands embrace properties of material objects, e.g. taste or odour, psycho-physiological features of a man, e.g. the ability for memorizing, emotional content of artwork or literature (music and poetic fragments, paintings, etc.) or advertising clips, and so on. The examples of similar tasks of fuzzy measurements can be found in the EU project "Measuring the Impossible".

2. Development of the measurement model for the field of humanities

In order that the measurement results could be applied by any people who are interested in them, it is necessary to provide metrological traceability of these results, i.e.:

• to provide the possibility of relating the measurement result to a reference which is specified and available for measuring or reproducing,
• to accompany the measurement result with the evaluation of its uncertainty.

In a common case, the requirement of the metrological traceability can be interpreted as the need to have:

• measurement model grounded for the conditions of the task being solved, and an appropriate equation \( Y = f(\alpha_i, \alpha_i ...\alpha_k) \), linking a measurand, \( Y \), with the parameters \( \alpha_i \) measured, where \( k \) is the number of various parameters (1 \( \leq i \leq k \)), \( k \) (at a required accuracy of the model of a phenomenon studied) being minimal.
• the reference established for each parameter being measured. The reference can be a definition of a measurement unit through its practical realization, or a measurement procedure, or a measurement standard [1].

The estimate of uncertainty of the value of \( Y \) can be obtained taking into account a methodical component of uncertainty due to inaccuracy of the proposed measurement model as well as the uncertainty of \( \alpha_i \).
The multiparametric measurements are rather widely spread. During many years they are often used in order to identify substances, to measure colour, to diagnose machines, etc. The development of the measurement model in these cases is not difficult.

Measurements in the domain of humanities offer significant problems, because the measurement models proposed usually are phenomenological, i.e. they are not causally determined. Therewith the experimental proof of their effectiveness for required field of application is time-consuming and causes significant expenses. Usage of the phenomenological measurement model grounded for measurements in a narrow domain, can lead to serious mistakes outside its limits which cannot be strongly defined in many cases. E.g., estimation of the recruit health on the basis of the results of a legal procedure of medical examination using measuring instruments, ignores a probability of infrequent diseases.

In order to decrease an amount of research and a probability of crude errors, it is expedient to seek a fuzzy measurement model grounded on physical, sociological, economical or other laws. This approach enables to suppose that $\alpha_i$ should be the quantities, the influence of which on $Y$ is the most significant. It is necessary to measure them according to the established measurement procedures. They should have a reference for comparison.

The efficiency of such an approach can be demonstrated using the development of the measurement model for determining emotional reaction to music fragments (or other acoustic fragments). Solving of this problem is useful for music theory, creation of new music instruments, automatic translation of speech and a lot of other applications.

3. Model for measurements of the emotional reaction of a listener

Mainly, in the models used for measuring the emotions they apply expert judgments as the parameters being measured. In some cases, the investigations are accompanied with an analysis of biophysical parameters of listeners. Experiments of this type permit to evaluate a posterior reaction of "testees" and in such a way to contribute to a better understanding of general regularities of its formation.

The emotions accompanying the human perception of acoustical influence can be estimated a priori with the help of measurements of a set of parameters characterizing this influence. For the corresponding measurement model, the most effective parameters $\alpha_i$ could be the parameters characterizing physiological processes, which can change depending on emotional condition of a listener (e.g. frequency of a process, intensity, sequence of variation of parameters, etc.).

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In order to determine a model, a following hypothesis was proposed [2]. Any acoustical influence carrying emotional information contains a sequence of signals - stimuli, perception and recognition of which in a corresponding order cause the generation of emotions.

In its turn, each of these stimuli can be characterized by one or a number of signals. Parameters of these signals can be measured and related to the known measurement units.

In other words, the emotion measurement equation can be written as:

$Y = f[X_1(\alpha_1, \alpha_\ldots \alpha_m), X_2(\alpha_1, \alpha_\ldots \alpha_m), \ldots, X_m(\alpha_1, \alpha_\ldots \alpha_m)]$

where $X_1$, $X_2$, $\ldots$, $X_m$ are the signals - stimuli and $m$ is the number of various signals - stimuli generating the whole set of emotions examined.

Thus, the solution of the problem of the model optimization when measuring the emotions, which are present in acoustical impacts can be brought to detection of both the above signals - stimuli and the parameters characterizing them.

The development of the model can be assisted with the evolutionary analysis of appropriate sensor systems [3].

Such systems were acquired by living creatures for providing them with the ability to adapt to changes of the environment. They became the means contributing to perceiving signals stimulating readiness for actions connected with approaching natural disasters.
enemies, as well as "food" or a male (female) animals. The concept of a signal implies a change in the environment, taking place within a rather short time period.

For living creatures appeared on the Earth in the ocean, the system providing the sense of touch became the most important sensor system. The sense of touch is related to the ability to perceive medium density changes caused by an earthquake or a moving body.

Since the auditory ability is the ability to perceive air oscillations, it is possible to make a conclusion that the foretype of the auditory system originated at the earliest stages of life formation. The sense of touch is inherent in the majority of living creatures.

The natural selection caused genesis of unconditioned reflexes for living creatures including those with weakly developed nervous system. These reflexes related to the responses on certain changes of medium density and became the foretype of emotions.

In particular, it is known that an approaching tsunami generates the oscillations of infrasound frequency and of a lower part of the sound frequency range (hereinafter, all these oscillations are referred to as IF oscillations), propagating in water. They give rise to a specific behaviour of living inhabitants of seas and oceans, including medusas, i.e. an attempt to escape. Similar reaction is typical for animals living on land. This effect can be explained by the following.

When reptiles left water and settled on land, where the density of a medium surrounding a large part of their bodies became significantly less, their sensitivity to IF oscillations giving danger signals, decreased.

The necessity for reptiles to keep the ability to perceive IF information of vital importance has resulted in emerging a more developed hearing aids. The living creatures gained the possibility to perceive the IF oscillations both directly and indirectly:

- by body using tactile sensation of the mechanical IF oscillations of ground or water and
- by "ear-brain" system perceiving the air oscillations of the sound frequency (SF) range and then recognizing the corresponding IF oscillations through a special conversion.

The IF oscillation recognition mechanism can be explained on the basis of the hypothesis that memorization and non-linear conversion of the SF oscillations is performed in the "ear-brain" system, where the IF oscillations causing the response of vital importance, are formed [4]. The well known experiments have shown that the IF oscillations can cause panic of people; while a long stay in silence leads to depression. Evidently, the reception of the signals confirming that the environmental processes take place in the regular way, contributes to emotional harmonization of behaviour.

The IF oscillations of a specific amplitude and frequency, are the signals-stimuli that define an elementary emotional response. This response is the emotional stress that prepares some subsequent action. It precedes the sense of fear, aggression, or happiness depending on additional previous or expected information.

The development of human society is connected with a more noticeable differentiation of dangers and more developed palette of emotional reactions. According to a famous biologist Dr. V. Dolnik, the Cro-Magnon man (unlike the Neanderthal man) survived because he managed to enrich the emotional SF oscillations he used, having put into them an emotionally rich logical content: he learned the art of speech.

At an extremely small number of IF oscillation parameters, a single way for enriching emotional information is the formation of emotional images from small ensembles of signals-stimuli and then the formation of more substantial information (emotional content) on the basis of integration of such ensembles. Presentation of such a kind resembles a speech structure with a limited number of sounds, incommensurably wider set of words and practically unlimited possibility to transfer substantial logical information.
Thus, when measuring emotions which are contained in acoustical impact, including musical fragments too, it is possible to use the frequency and level of IF signals-stimuli (or some other parameters analogue to them) as the model parameters $\alpha_1$ and $\alpha_2$ being measured. In our point of view, the emotions emerging due to perception of parameters other than acoustical ones also have been formed by means of integrating the groups of stimuli.

4. Research of the model efficiency

In order to research the model efficiency, it was proposed to use a key and tonality as a foundation, since they are comparatively simple musical characteristics related to emotions. The tonalities were identified by tonic triads which are the basic elements of tonalities.

The main results of calculations have shown the following:

- The oscillations that relate to the sounds forming tonic triads and thirds, while interacting in the non-linear system, really cause the IF combinative components.
- The difference in emotional perception of the major key and minor key corresponds to the difference in the IF combinative component spectrum. The major key is characterized by IF combinative components of much higher level than the minor one.
- The “ear-brain” system is characterized by inertness (memory).
- Order and frequencies of combinative components depend on a tonic.
- For the ancient Pythagorean scale, the difference between various tonalities are significantly greater than for the even-tempered one.

The results of analysis show that the signals-stimuli stimulating elementary emotional response can be singled out and quantitatively evaluated.

The IF signals-stimuli belong to the range corresponding to various bio-rhythms. Probably, the genetic fixation of the response to the IF oscillations and their combinations was realized on the basis of the proximity of the IF frequencies that are important for the emotions to the frequencies of the processes that are important for physiology (bio-rhythms).

These conclusions can be illustrated by analysis of fragments of African ethnic music performed on drums. They have characteristic titles: "Fear" (Fig. 1a) and "Shindig" (Fig. 1b). In these figures, we can see the difference in the IF spectra, obtained at the output of a non-linear converter. Also, we can notice that the number of IF maximums determining the expected emotional reaction of a listener, is small.

![Fig. 1. Examples of the IF spectra obtained at the output of a non-linear converter](image)

Statistically reliable expert judgments of the listener's reaction to the classical musical compositions [5] were taken into consideration. They gave the basis for the conclusion that the simplest emotional image includes a sequence of not fewer than three IF signal-stimuli. They are the tonic triads of relative tonalities (according to steps I-IV-V and I-IV-V-I).

Such emotional images can cause more varied emotional reactions, i.e. contemplativeness, aloofness, or joy. If the sequence of the IF signals-stimuli changes, new emotional image is forming. Its colour depends on previous and/or subsequent emotional images.

The sequence of the simplest emotional images defines the emotional content of music.
The proposed interpretation of the idea of the simplest emotional image can be proved by a correlation between statistically reliable emotional reaction of listeners to fragments of classical musical compositions written in special tonalities and graphic representation of the mentioned emotional images in the field of bio-rhythms. Results of the computer experiments with chords and music fragments confirmed the conclusions drawn from the calculating analysis and revealed a great role of the articulation of sound.

The above said proves that a special device can be developed, which will evaluate the expected emotions of music. The emotional response on these signals and stimuli for people with healthy psychic will have a comparatively sharp distribution curve. This reaction is typical. Dispersion of the type A evaluation of uncertainty depends on the state of health and mood of the testees. For its decrease it is useful to carry out a preliminary emotional adjustment, i.e. prepare the testees for experiments, to relieve their internal stress, etc.

Deviation of emotional reaction of a person from the typical one, defined a posteriori, can serve as an indicator of some mental troubles. Reaction for more complicated acoustic impacts depends on cultural traditions, psychological type and mood of the testees.

5. Conclusion

In order to improve the traceability of fuzzy measurements in the field of humanities it is proposed to seek a multiparametric measurement model characterized by a minimal set of measuring parameters. Each of these parameters should have an established reference for comparison. In this case the corresponding measurement complies with the widely defined concept of measurement and is maximum close to the concept of "strongly defined measurement" [6].

It was shown that the search of such a model can be facilitated with the help of the evolutionary or historical analysis. The suggestions given were grounded using the development of the measurement model for determining emotional reaction to music fragments.

References