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Mutual-probability prediction and higher-order correlation effects among acoustic, light and electromagnetic waves in a video display terminal environment

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Abstract

A probabilistic signal processing method, with which is possible to get some methodological suggestion to the measurement method of correlative and/or accumulative effects in the compound environment of sound, light and electromagnetic (EM) waves is discussed. In order to extract various types of latent interrelation characteristics among wave environmental factors leaked from an actually operating video display terminal (VDT), an extended regression system model, hierarchically reflecting not only linear correlation information but also nonlinear correlation information, is first introduced, especially from a viewpoint of 'relationism-first'. Then, through estimating each regression parameter of this model, some original evaluation methods for predicting a whole probability distribution form, from one another, are proposed. Finally, the effectiveness of the methods is experimentally confirmed, by applying them to the actual observed data leaked by a VDT with some television games. ***To cite this article: M. Ohta et al., C. R. Mecanique 333 (2005).***

Résumé

Prédiction de probabilité mutuelle et les effets de corrélation d'ordre supérieur entre les ondes acoustiques, électromagnétiques et optiques dans l'environnement d'une console vidéo. On discute une nouvelle méthode de traitement du signal susceptible d'apporter quelques suggestions d'ordre méthodologique concernant les procédés permettant de mesurer les effets corrélatifs et/ou cumulatifs dans un environnement où interagissent simultanément la lumière, les ondes électromagnétiques et acoustiques. Afin de pouvoir extraire de différents types d'interrelations caractéristiques latentes entre les facteurs provenant d'une console terminale vidéo en action, nous avons introduit un modèle étendu d'un système régressif rendant compte de ma-

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nière hiérarchisée, non seulement l'information sur la corrélation linéaire, mais aussi nonlinéaire, du point de vue privilégient les « relations d'abord ». Ensuite, après avoir estimé chaque paramètre régressif de ce modèle, de nouvelles méthodes d'évaluation sont proposées permettant la prédiction de la distribution des probabilités toute entière. Finalement, l'efficacité de nos méthodes est confirmée expérimentalement grâce aux données provenant des consoles de certains jeux vidéo. ***Pour citer cet article : M. Ohta et al., C. R. Mecanique 333 (2005).***

Keywords: Waves; Biomechanics; Mutual-probability prediction; Higher-order correlation effects; Wave environmental factors; Video display terminal environment

Mots-clés : Ondes ; Biomécanique ; Prédiction de probabilité mutuelle ; Effets de correlation d'ordre superieur ; Facteurs d'environnement d'ondes ; Environnement d'une console video

1. Introduction

In their everyday life, most humans are surrounded by various kinds of stimulating waves such as sound, light and electromagnetic (EM) waves. In addition to their direct biological effects, these waves interact in a complex manner with natural, social and human factors of the environment. These combined effects become an important issue, given the constant increase of electric equipment that people use, such as personal computers or portable radio transmitters, and the need for some new method of measurement and evaluation of these effects has been clearly demonstrated [1].

In this Note, a stochastic approach is presented, that grasps the mutual relationship among sound, light and EM waves (especially in the science and engineering fields) produced by a video display terminal (VDT) in an actual working environment. This approach, already described elsewhere [2–6] uses an extended regression analysis [7] that reflects both the linear and nonlinear correlations among variables. More specifically, in order to predict their probability distribution, we propose a parameter estimation method, based on an internal statistical architecture of the joint probability among variables. A simple experiment is then described, the results of which confirm partly the effectiveness of our method.

2. Theory

In order to evaluate quantitatively and hierarchically the relationship between two variables (e.g. time functions corresponding to an acoustic wave and a light wave), we introduce a generalized regression-analysis method (see [7] and also [8–11]), employing not only the linear correlation, but also the nonlinear correlation information among many stochastic variables. In particular, in the case of a prediction variable x and a criterion variable y, the regression function as a typical regression relationship between x and y can be explicitly given, as follows:

$$\langle y \mid x\rangle = \frac{\sum_{m=0}^{\infty}\sum_{n=0}^{1} C_{1n} A_{mn}\varphi_m^{(1)}(x)}{\sum_{m=0}^{\infty} A_{m0}\varphi_m^{(1)}(x)} \tag{1}$$

$$A_{mn} \equiv \left\langle \varphi_m^{(1)}(x)\varphi_n^{(2)}(y)\right\rangle_{x,y} \tag{2}$$

where $\langle\cdot\rangle$ denotes the averaging operation with respect to the random variables and $\varphi_m^{(1)}(x)$ and $\varphi_n^{(2)}(y)$ are orthonormal polynomials with two weighting functions $P_0(x)$ and $P_0(y)$, respectively. The coefficients C_{10} and C_{11} are calculated in advance through employing an orthogonal series expansion expression of y by use of the orthonormal polynomial $\varphi_n^{(2)}(y)$. The information on the various types of linear and nonlinear correlations between x and y is reflected hierarchically in each expansion coefficient A_{mn} [12]. Thus, after estimating the expansion coefficient

A_{mn} defined by Eq. (2) on the basis of the observed data on x and y, the regression function between x and y can be evaluated by Eq. (1).

Furthermore, a specific probability distribution $P_s(y)$ based on an arbitrary type random fluctuation of a regressively related stochastic variable x can be predicted, as follows:

$$P_s(y) = P_0(y)\sum_{n=0}^{\infty} B_n \varphi_n^{(2)}(y) \tag{3}$$

$$B_n = \left\langle \frac{\sum_{m=0}^{\infty} A_{mn}\varphi_m^{(1)}(x)}{\sum_{m=0}^{\infty} A_{m0}\varphi_m^{(1)}(x)} \right\rangle_x \tag{4}$$

In this Note, in order to ensure the theoretical foundation connected to the evaluation and measurements (e.g., the Specific Absorption Ratio (SAR) [1], frequently used in the field of biological effects of EM waves), let us assume that both of the prediction variable x and the criterion variable y are energy quantities or observed on a intensity scale. In this case, the well-known Gamma distribution can be reasonably chosen as two fundamental probability functions $P_0(x)$ and $P_0(y)$, as follows:

$$P_0(x) = \frac{1}{\Gamma(m_x)S_x}\,\mathrm{e}^{-x/S_x}\left(\frac{x}{S_x}\right)^{m_x-1} \tag{5}$$

$$P_0(y) = \frac{1}{\Gamma(m_y)S_y}\,\mathrm{e}^{-y/S_y}\left(\frac{y}{S_y}\right)^{m_y-1} \tag{6}$$

where, $m_x(=\mu_x^2/\sigma_x^2, \mu_x = \langle x\rangle, \sigma_x^2 = \langle (x-\mu_x)^2\rangle)$, $S_x(=\mu_x/m_x)$, $m_y(=\mu_y^2/\sigma_y^2, \mu_y = \langle y\rangle, \sigma_y^2 = \langle (y-\mu_y)^2\rangle)$ and $S_y(=\mu_y/m_y)$ denote the parameters of the Gamma distribution. Thus, by utilizing Laguerre polynomials: $\mathrm{L}_i^{(\cdot)}(\cdot)$, the orthonormal polynomials: $\varphi_m^{(1)}(x)$ and $\varphi_n^{(2)}(y)$ can be recovered, as follows:

$$\varphi_m^{(1)}(x) = \sqrt{\frac{m!\Gamma(m_x)}{\Gamma(m_x+m)}}\,\mathrm{L}_m^{(m_x-1)}\left(\frac{x}{S_x}\right) \tag{7}$$

$$\varphi_n^{(2)}(y) = \sqrt{\frac{n!\Gamma(m_y)}{\Gamma(m_y+n)}}\,\mathrm{L}_n^{(m_y-1)}\left(\frac{y}{S_y}\right) \tag{8}$$

Consequently, the regression function $\langle y \mid x\rangle$ in Eq. (1) and the regression parameter A_{mn} in Eq. (2) can be expressed, respectively, as follows:

$$\langle y \mid x\rangle = m_y S_y - \sqrt{m_y}S_y \frac{\sum_{m=0}^{\infty} A_{m1}\sqrt{m!\Gamma(m_x)/\Gamma(m_x+m)}\,\mathrm{L}_m^{(m_x-1)}(x/S_x)}{\sum_{m=0}^{\infty} A_{m0}\sqrt{m!\Gamma(m_x)/\Gamma(m_x+m)}\,\mathrm{L}_m^{(m_x-1)}(x/S_x)} \tag{9}$$

$$A_{mn} \equiv \left\langle \sqrt{\frac{m!\Gamma(m_x)}{\Gamma(m_x+m)}}\,\mathrm{L}_m^{(m_x-1)}\left(\frac{x}{S_x}\right)\sqrt{\frac{n!\Gamma(m_y)}{\Gamma(m_y+n)}}\,\mathrm{L}_n^{(m_y-1)}\left(\frac{y}{S_y}\right)\right\rangle_{x,y} \tag{10}$$

Furthermore, from Eqs. (5)–(8), the specific probability distribution $P_s(y)$ in Eq. (3) and the parameter B_n in Eq. (4) can be finally expressed, as follows:

$$P_s(y) = \frac{1}{\Gamma(m_y)S_y}\,\mathrm{e}^{-y/S_y}\left(\frac{y}{S_y}\right)^{m_y-1}\sum_{n=0}^{\infty} B_n\sqrt{n!\Gamma(m_y)/\Gamma(m_y+n)}\,\mathrm{L}_n^{(m_y-1)}\left(\frac{y}{S_y}\right) \tag{11}$$

$$B_n = \left\langle \frac{\sum_{m=0}^{\infty} A_{mn}\sqrt{m!\Gamma(m_x)/\Gamma(m_x+m)}\,\mathrm{L}_m^{(m_x-1)}(x/S_x)}{\sum_{m=0}^{\infty} A_{m0}\sqrt{m!\Gamma(m_x)/\Gamma(m_x+m)}\,\mathrm{L}_m^{(m_x-1)}(x/S_x)} \right\rangle_x \tag{12}$$

3. Experiment

An experiment was run in which the acoustic, light and electromagnetic fields produced by a VDT were measured, while playing television games in an actual working environment. No EM background noise was detectable. Measurements were made continuously over a period of 7200 s. The acoustic pressure was somewhat intermittent, and varied substantially in time, but overall the level was of the order of 75 dBA. Luminance was switched regularly from a rather stable value of about 15 lx to another stable value of 58 lx. The electric field was highly variable too, behaving as a series of pulses covering the range of 1.8 to 3.8 (V/m). Sound pressure level was measured with a 22331 Bruel & Kjar level meter, illumination with a Minolta illuminometer, and electric potential with an HI-3603 field survey meter from Holaday Industries Inc. The recordings of these highly fluctuating fields were simultaneously sampled, with a sampling interval of 10 s, which provided three sets of 720 data points.

3.1. Mutual prediction and specific probability distribution

The regression parameter A_{mn} is first calculated, using Eq. (10), from the first 500 data points. Next, based on the remaining 220 data, the specific probability distribution is predicted. Figs. 1 to 4 describe the results of the regression analysis. Figs. 1 and 2 show the experimental results for the regression analysis from sound pressure level to illumination and from illumination to electric field strength, respectively. Figs. 3 and 4 show the experimental

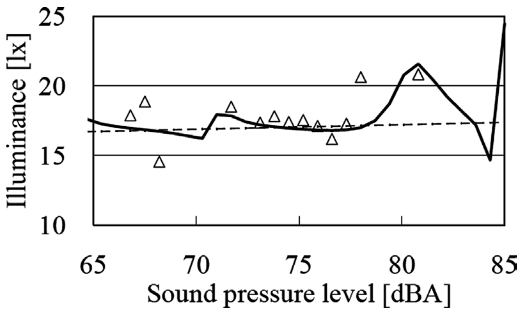

Fig. 1. A comparison between theoretical curves (– – – : 1st. approx., — : 8th. approx.) and experimentally sampled points (△) for the regression characteristics (from sound to light).

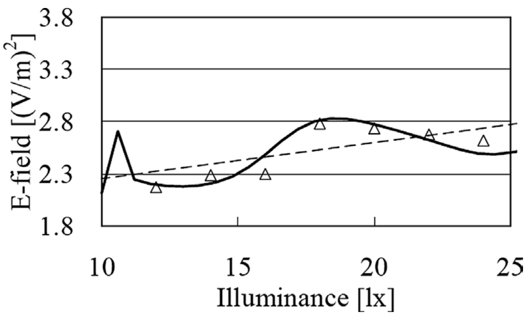

Fig. 2. A comparison between theoretical curves (- - - : 1st. approx., — : 13th. approx.) and experimentally sampled points (△) for the regression characteristics (from light to electric field).

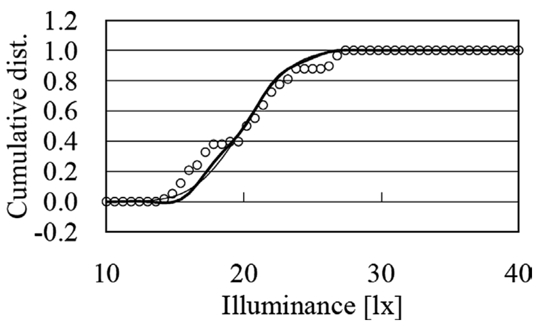

Fig. 3. A comparison between theoretically predicted curves (— : 1st. approx., — : 8–15th. approx.) and experimentally sampled points (○) for the specific probability distribution (from sound to light).

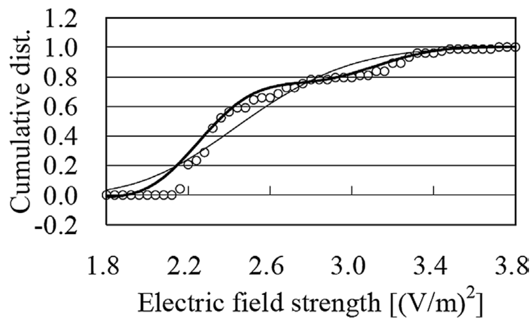

Fig. 4. A comparison between theoretically predicted curves (— : 1st. approx., — : 13–9th. approx.) and experimentally sampled points (○) for the specific probability distribution (from light to electric field).

results for the prediction of the specific probability distribution from sound pressure level to illumination and from illumination to electric field strength, respectively. From these figures, it can be found that the theoretical curves show a fairly good agreement with the experimentally sampled points.

4. Conclusion

In this Note, firstly, a stochastic methodology has been discussed in close connection with the mutual relationship amongst sound, light and EM waves leaked from a VDT in an actual working environment, in particular, through a system model based on an extended regression analysis reflecting not only linear but also nonlinear correlation information. More specifically, in order to mutually predict their probability distribution from one to another, we have proposed a parameter estimation method based on an internal statistical architecture of the joint probability among these wave factors in an ideal situation without a background noise. Finally, the effectiveness of our proposed method has been confirmed through the principle experiment of applying it to the observation data leaked from a VDT with a television game in the room of an actual working environment. Furthermore, since it seems noteworthy, the background basic idea on the necessity of first taking the above mutual intermediation among many different environmental factors into consideration is now briefly described.

It is said that we humankind have been first born from nature consisting of substances in the eternal evolution process after the Birth of the Macrocosm. Accordingly, for existence of all things, at the bottom of its specific concrete qualitative reflection, there exists inseparably the correlative and quantitative reflection as the logos of substances. It seems that the mutual intermediation between them should be essential as some existence principles are considered as any first great interest.

In this study, first we have dared to take a standpoint based on an essential principle: ‘relationism-first’ on the existence of all things, differing from a standpoint of ‘separatism-first’. That is, every linear and nonlinear type multi-correlation analysis among all kinds of different environmental factors (including even social and human factors) should be deeply and diversely considered at the first stage of a study (as a quest for truth). After that, by decomposing the compound correlation effects into each factor, our specific interesting factor should be separately studied (as a quest for effectiveness) according to the main purpose of our investigation.

More concretely, after passing through the relationally mathematical (sometimes physical) basic logic, next, from the viewpoint of intersubjectivity, as an example in the present main object of study, we have focused selectively on the form of subjective behavior of only one environmental factor in the form of the probability distribution.

Furthermore, as practical examples on the necessity of introducing some ideas of relationism-first, let us see many actual phenomena composed of extensive environmental factors in different fields with the mutual relationships among them. The nervous system of mankind is very much affected by any field of sound, light or electromagnetic wave in the neighborhood of the specific frequency band from 15 Hz to 20 Hz (because calcium ions are occasionally lost). This seems to be particularly induced by the signal modulated into a high frequency band with the slow change of its envelope amplitude. Furthermore, the generated order, generated time interval, each having their proper duration between sound and flush of lightening, cannot be recognized correctly in a living body. There are some biological priority effects between human senses. For example, the sense of hearing is affected by the sense of sight with stronger ability of evoking attention, and also there are promotion effects between different senses, and synergistic effect between senses and stress (for example, participation in VDT syndrome such as general malaise, relevance to circadian rhythm due to the effect on the pineal body of the exposure to light and electromagnetic fields, changes of brain waves in the case when we have received sound and light at the same time, chromesthesia, cooperation effect of music and visual images and so on). Nowadays, the generation of many modern population problems and the development of high technology seem to be essentially two sides (facility and risk) of the same coin, which should be originally supported by the idea of relationism-first.

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