Type of the Paper - Research article, expanded version of the conference paper
Azarov, O.; Krupelnitsky, L.; Rakytyanska, H. A fuzzy model of television rating control with trend rules tuning based on monitoring results. In Proceedings of the 2018 IEEE Second International Conference on Data Stream Mining & Processing (DSMP); Lviv, Ukraine, August 21-25, 2018, pp. 369-375. ISBN: 978-1-5386-8175-6

Television Rating Control in the Multichannel Environment Using Trend Fuzzy Knowledge Bases and Monitoring Results

Olexiy Azarov [1], Leonid Krupelnitsky [1] and Hanna Rakytyanska [2,*]

[1] Vinnytsia National Technical University, Computer Facilities Department, 95, Khmelnitske sh., Vinnytsia, Ukraine, 21021, azarov2@vntu.edu.ua, krupost@gmail.com
[2] Vinnytsia National Technical University, Soft Ware Design Department, 95, Khmelnitske sh., Vinnytsia, Ukraine, 21021, h_rakit@ukr.net
* Correspondence: h_rakit@ukr.net; Tel.: +38-0432-61-68-02

Abstract: The purpose of the study is to control the ratio of programs of different genres when forming the broadcast grid in order to increase and maintain the rating of the channel. In the multichannel environment, television rating control consists of selecting such content, ratings of which are completely restored after advertising. A hybrid approach combining the benefits of semantic training and fuzzy relational equations in simplification of the expert recommendation systems construction is proposed. The problem of retaining the television rating can be attributed to the problems of fuzzy resources control. The increase or decrease trends of the demand and supply are described by primary fuzzy relations. The rule-based solutions of fuzzy relational equations connect significance measures of the primary fuzzy terms. Rules refinement by solving fuzzy relational equations allows avoiding labor-intensive procedures for the generation and selection of expert rules. The solution set generation corresponds to the granulation of the television time, where each solution represents the time slot and the granulated rating of the content. In automated media planning, generation of the weekly TV program in the form of the granular solutions provides the decrease of the time needed for the programming of the channel broadcast grid.

Datasets:
TV Channel Inter: Ratings. Available online: http://inter.ua/uk/about/rating
TV Channel Inter: Weekly TV Program. Available online: https://inter.ua/uk/tv
IMDb Top Rated Movies. Available online: https://www.imdb.com
Ukrainian Films Catalog. Available online: https://kinoafisha.ua/ratings/

Dataset License: open access data set

Keywords: TV channel rating, expert recommendation systems, fuzzy resources control, fuzzy classification knowledge bases, solving fuzzy relational equations.

Preprints (www.preprints.org) | NOT PEER-REVIEWED | Posted: 5 November 2018 doi:10.20944/preprints201811.0092.v1

Peer-reviewed version available at Data 2018, 3, 57; doi:10.3390/data3040057

1. Summary

The top priority task of the personnel of TV companies is to control the ratio of programs of different genres when forming the broadcast grid in order to increase and maintain the rating of the channel [1]. The rating of a television channel is determined by specialized sociological services and directly affects the cost of advertising time. Content management is modeled by integrating trials, expert recommendations and users' preferences [2]. The recommendation accuracy strongly depends on the mechanisms of the supply and demand regulation [3], which consider time factors and users' preferences simultaneously [4, 5]. Parametric statistical models are widely used to evaluate the viewers' demand and the popularity of TV programs [6–9]. These models are adjusted to fit the distribution of user ratings in video on demand services dealing specifically with TV content [6, 7]. To enhance the recommendation accuracy, the statistical models aim to learn audience preferences that follow from the rich user content generated in the social networks [8, 9]. The timing and item recommendations are generated via clustering the common interests of a group of people [10, 11]. Finally, the cognitive models describe the behavior of viewers when choosing a TV channel [12, 13]. Such models predict program commitments based on viewer-program emotional relationships reflecting satisfaction and perception toward alternative programs.

The television domain has become increasingly complex due to the multichannel environment. Television advertising time is purchased on the basis of the projected future ratings [14]. The problem lies in the paradoxical connection between the programs ratings before and after the ad unit [15]. In the multichannel environment, the ad skipping behaviors may result in the lower ratings [16]. Restoration of the program rating after the ad unit depends on the decision to watch or skip the program, i.e. give preference to the programs broadcast by the concurrent channels. The conventional recommender systems concentrate on the targeted advertising and do not take the ad break-factor into account [17, 18]. In this case, the skipping phenomenon stipulated by the multichannel environment is ignored. Such methods of media planning will inevitably reduce the rating points because of the content sensitivity to the advertisement insertion [18].

The problem of retaining the television rating can be attributed to the problems of fuzzy resources control [1, 19]. In such models, the "demand-supply" relationships are described by fuzzy IF-THEN rules. In works [19, 20], it is suggested to build the fuzzy resources control model on the grounds of the general method of nonlinear dependencies identification by means of fuzzy knowledge bases. The method [19, 20] implies the stage of tuning the fuzzy control model using "demand-supply" training data. The tuning stage consists of finding such fuzzy rules weights and such membership functions forms, which provide maximum proximity of the results of fuzzy logic inference to the correct managerial decisions.

In work [21], the fuzzy control model, which provides the balanced demand and supply for each content category was proposed. Experienced managers make effective administrative decisions based on a comparison of the viewers' demand for the programs of different genres with the rating of the programs offered at the given time. Dependent upon this, a control action is formed, which consists of increasing or decreasing the rating of the programs in the channel broadcast grid [21].

Unlike [21], the fuzzy control model is expanded on the account of the supplementary factors influencing the demand and supply. The viewers' demand for different content categories is defined by the time factors, i.e. the time of viewing and the day of the week. In the multichannel environment, television rating control consists of selecting such content, ratings of which are completely restored after advertising. Therefore, projected ratings after control in each genre category are evaluated by the content attributes and the ad break-factor. In this case, targeted advertising is augmented by the viewer intention to watch the program. Finally, the content category for each time slot is recommended on the grounds of users' preferences.

The construction of expert recommendation systems is associated with computational costs. Constantly changing preferences of different categories of viewers require the selection and adjustment of the appropriate set of expert rules. At the same time, experts establish the trends of demand-supply relationships, which are subject to further refinement. Such trend dependencies are described by primary fuzzy knowledge bases. In this case, the increase or decrease of the television indices can be considered as the primary fuzzy terms. The solution to the problem of expert rules refinement may be the use of fuzzy relational equations [22, 23], the solutions of which represent the linguistic modification of the primary terms. The obtained solutions can be considered as composite fuzzy rules that connect significance measures of the primary fuzzy terms and reflect the semantic intensiveness of the increase or decrease trend [24-27]. The number of rules is determined by the number of solutions. The recommendation accuracy is achieved through the complete solution set, i.e. the complete rule set of the recommendation knowledge base [28, 29].

The composite fuzzy model of the control action balancing the demand and supply was proposed in [21]. In this paper, the composite fuzzy models for the demand and supply are proposed. The composite fuzzy model of the demand defined by the time factors allows generating item and timing recommendations simultaneously. The composite fuzzy model of the supply defined by the content and advertisement attributes provides the rating restoration in the multichannel environment. Refinement of the rule set by solving fuzzy relational equations allows avoiding labor-intensive procedures for the generation and selection of expert rules. The solution set generation corresponds to the granulation of the television time, where each solution represents the time slot and the granulated rating of the content. In automated media planning, generation of the weekly TV program in the form of the granular solutions provides the decrease of the time needed for the programming of the channel broadcast grid. Therefore, it is important to develop a hybrid approach combining the benefits of semantic training [19, 20] and fuzzy relational equations [24–27] in simplification of the process of expert recommendation systems construction. Following the approach proposed in [24–27], the genetic-neuro algorithm is used for tuning the primary fuzzy model and solving the primary system of fuzzy relational equations [28, 29].

2. Data Description

The fuzzy model of resources management was constructed using the example of the television channel Inter, which holds leading positions in the Ukrainian media market [30]. The TV channel Inter presents programs of such basic genres: political programs and news releases ($k=1$); TV serials and documentary projects ($k=2$); entertaining and sports programs ($k=3$).

For the TV rating control problem, the monitoring and forecast window will be for one week. We shall denote the time and day of the week for the TV program release as $\mathbf{t}=(t_1, t_2)$. Management is carried out at the level of each air-hour, i.e. $t_1 \in [0, 24]$, $t_2 \in [1, 7]$. Let p be the number of the current week for media planning. The proportion of TV viewers who watch TV at the time moment ($\mathbf{t}$, p) determines the rating of the TV channel. For the channel Inter, the ratings reach 20%. The analysis of the TV channel rating is carried out according to the results of monitoring of the

Preprints (www.preprints.org) | NOT PEER-REVIEWED | Posted: 5 November 2018 doi:10.20944/preprints201811.0092.v1

Peer-reviewed version available at Data 2018, 3, 57; doi:10.3390/data3040057

TV programs ratings obtained for the previous week p-1. The TV program is compiled for the forthcoming week p.

The timing and item recommendations in the form of the weekly TV program is presented in [31]. The weekly TV program is compiled as a grid with the following nodes: the date (the time of viewing and the day of the week) and the attributes of the program (the genre and title of the program).

The popularity estimates of the TV programs included in the weekly broadcast grid can be obtained from the Internet Movie Data Base (imdb) [32]. This data set contains nearly 5000 titles of the top rated TV shows in 26 genre categories. Imdb-ratings of the TV shows produced in Ukraine are collected in [33]. In developing fuzzy model of resources control, we shall use the imdb-ratings as the supply attributes weighted using the scale from 0 to 10 [32, 33].

Effectiveness of time and content management is evaluated by the weekly top 20 rating [30]. The archive of weekly ratings contains data from 2012-2018 years. The weekly top 20 can be represented as a table with the following columns: the title of the program, the date and time, the rating and share. The weekly top 20 list contains the ratings influenced by the ad break-factor. The ad break-factor can be considered as a proportion of viewers who return to the program after advertising. TV experts connect the ad break-factor with the lowering down of the possible ratings up to 40%.

Ratings of the programs, which do not fall into the weekly top 20 list are evaluated as follows. It is obvious, that the ratings of these programs do not exceed the minimum value among the most popular weekly programs. For the newly launched TV shows, the imdb-ratings can be temporarily substituted by the actual ratings from the weekly top 20 list.

3. Method of the Recommendation System Construction

3.1. Structure of the TV Rating Control Model

The structure of the TV rating control model corresponds to the following hierarchical tree of logic inference:

- for content management

$$x_k = f_x^k(t_1, t_2, p), \quad k = \overline{1,n}, \tag{1}$$

$$y_k(\mathbf{t}, p) = f_y^k(x_k(\mathbf{t}, p), z_k(\mathbf{t}, p-1)), \tag{2}$$

- for rating evaluation

$$a_k(\mathbf{t}, p) = f_a^k(x_k(\mathbf{t}, p)), \tag{3}$$

$$v_k(\mathbf{t}, p) = f_v^k(z_k(y_k(\mathbf{t}, p)), a_k(\mathbf{t}, p)), \tag{4}$$

$$u(\mathbf{t}, p) = f_u(v_1(\mathbf{t}, p)), \ldots, v_n(\mathbf{t}, p)), \tag{5}$$

where n is the number of genres of the TV programs;

$x_k(\mathbf{t}, p)$ is the viewers' demand for the programs of the genre k at the time moment $(\mathbf{t}, p)$;

$z_k(\mathbf{t}, p-1)$ is the imdb-rating of the program of the genre k at the time moment $(\mathbf{t}, p-1)$;

Preprints (www.preprints.org) | NOT PEER-REVIEWED | Posted: 5 November 2018 doi:10.20944/preprints201811.0092.v1

Peer-reviewed version available at Data 2018, 3, 57; doi:10.3390/data3040057

$y_k(\mathbf{t}, p)$ is a control action for the time moment $(\mathbf{t}, p)$, consisting in increasing–decreasing the imdb-rating of the program of the genre k;

$z_k(y_k(\mathbf{t}, p))$ is the imdb-rating of the program offered after the control action;

$a_k(\mathbf{t}, p)$ is the break-factor of the program of the genre k with the advertisement at the time moment $(\mathbf{t}, p)$;

$v_k(\mathbf{t}, p)$ is the rating of the program of the genre k restored after the ad unit at the time moment $(\mathbf{t}, p)$;

$u(\mathbf{t}, p)$ is the rating of the TV channel at the time moment $(\mathbf{t}, p)$.

It is supposed that the control action is determined as the difference between the imdb-rating values before and after control, i.e. $y_k(\mathbf{t}, p) = z_k(\mathbf{t}, p) - z_k(\mathbf{t}, p-1)$.

Variation ranges of the TV indices are defined as follows: [0, 10] points for x_k and z_k; [-10, 10] points for y_k; [0.4, 1] for a_k; [0, 20] % for v_k and u.

We shall describe the trend dependencies with the help of the primary fuzzy terms:

- in the morning (M), in the afternoon (A), in the evening (Ev) for t_1;
- on weekdays (Wd), on weekends (We) for t_2;
- increased (decreased) (I, D) or stable (St) for x_k, z_k, v_k or u;
- increase (decrease) (I, D) or stay inactive (N) for y_k.

For the composite knowledge base construction, we shall use the linguistic modifiers: sharply (sh), moderately (m), weakly (w). These modifiers describe the semantic intensity of the primary terms D and I [26, 27].

Functional dependencies (1)-(5) are defined by the primary fuzzy relations presented in Tables 1-5.

It is necessary to transfer the primary fuzzy relations into the composite fuzzy rules for the modified decision classes of the variables $x_k(\mathbf{t}, p)$, $y_k(\mathbf{t}, p)$, $a_k(\mathbf{t}, p)$, $v_k(\mathbf{t}, p)$ and $u(\mathbf{t}, p)$. The composite rules were built for the seven classes (sh-m-wD, St, w-m-shI) of the variables $x_k(\mathbf{t}, p)$, $a_k(\mathbf{t}, p)$, $v_k(\mathbf{t}, p)$, $u(\mathbf{t}, p)$; for the seven classes (sh-m-wD, N, w-m-shI) of the variable $y_k(\mathbf{t}, p)$.

Table 1. Primary fuzzy relations "viewing time - demand"

IF		**THEN** $x_k(\mathbf{t}, p)$		
		D	St	I
t_1	M	w-m	m	w-m
	A	m	m-sh	m
	Ev	w	m-sh	sh
t_2	Wd	m-sh	sh	m-sh
	We	m	m-sh	m-sh

Peer-reviewed version available at *Data* **2018**, *3*, 57; doi:10.3390/data3040057

Table 2. Primary fuzzy relations "demand and supply – control action"

IF		THEN $y_k(\mathbf{t},p)$		
		D	N	I
$x_k(\mathbf{t},p)$	D	sh	sh	w
	St	m-sh	m-sh	sh
	I	w	m	sh
$z_k(\mathbf{t},p-1)$	D	w	sh	sh
	St	m-sh	m-sh	m
	I	sh	m	w

Table 3. Primary fuzzy relations "demand – ad break-factor"

IF		THEN $a_k(\mathbf{t},p)$		
		D	St	I
$x_k(\mathbf{t},p)$	D	m-sh	w-m	w
	St	w-m	m-sh	w-m
	I	w	m	sh

Table 4. Primary fuzzy relations "supply with the ad break-factor – restored genre ratings"

IF		THEN $v_k(\mathbf{t},p)$		
		D	St	I
$z_k(\mathbf{t},p)$	D	sh	w	w
	St	m	m-sh	m
	I	m	m-sh	sh
$a_k(\mathbf{t},p)$	D	sh	w	w
	St	m	m-sh	w-m
	I	w-m	m-sh	sh

Table 5. Primary fuzzy relations "restored genre ratings – rating of the channel"

IF		THEN $u(\mathbf{t},p)$		
		D	St	I
$v_k(\mathbf{t},p)$	D	m-sh	w-m	w
	St	w-m	m-sh	m-sh
	I	w	w-m	sh

3.2. The Problem of Tuning the Fuzzy Control Model

The fuzzy control model connects the vectors of significance measures of the primary fuzzy terms of the variables t_1, t_2, x_k, z_k and y_k in correlations (1), (2); variables x_k, a_k, z_k, v_k and u in correlations (3)-(5).

Correlations (1)-(5) define the primary fuzzy model in the form:

Preprints (www.preprints.org) | NOT PEER-REVIEWED | Posted: 5 November 2018 doi:10.20944/preprints201811.0092.v1

Peer-reviewed version available at Data 2018, 3, 57; doi:10.3390/data3040057

- for content management

$$\boldsymbol{\mu}_x^k = (\boldsymbol{\mu}_t^1 \circ \mathbf{H}_1^k) \cap (\boldsymbol{\mu}_t^2 \circ \mathbf{H}_2^k)\,, \tag{6}$$

$$\boldsymbol{\mu}_y^k = (\boldsymbol{\mu}_x^k \circ \mathbf{Q}_1^k) \cap (\boldsymbol{\mu}_z^k \circ \mathbf{Q}_2^k)\,, \tag{7}$$

- for rating evaluation

$$\boldsymbol{\mu}_a^k = \boldsymbol{\mu}_x^k \circ \mathbf{G}^k\,, \tag{8}$$

$$\boldsymbol{\mu}_v^k = (\boldsymbol{\mu}_Z^k \circ \mathbf{R}_1^k) \cap (\boldsymbol{\mu}_a^k \circ \mathbf{R}_2^k)\,, \tag{9}$$

$$\boldsymbol{\mu}_u = (\boldsymbol{\mu}_v^1 \circ \mathbf{W}^1) \cup \ldots \cup (\boldsymbol{\mu}_v^n \circ \mathbf{W}^n)\,, \tag{10}$$

where $\boldsymbol{\mu}_t^1 = (\mu_t^{1,1},\ldots,\mu_t^{1,3})$ and $\boldsymbol{\mu}_t^2 = (\mu_t^{2,1},\mu_t^{2,2})$ are the vectors of the fuzzy causes M, A, Ev and Wd, We for the variables t_1 and t_2;

$\boldsymbol{\mu}_x^k = (\mu_x^{k,1},\ldots,\mu_x^{k,3})$ and $\boldsymbol{\mu}_z^k = (\mu_z^{k,1},\ldots,\mu_z^{k,3})$ are the vectors of the fuzzy causes D, St, I for the variables x_k and z_k;

$\boldsymbol{\mu}_y^k = (\mu_y^{k,1},\ldots,\mu_y^{k,3})$ is the vector of the fuzzy effects D, N, I for the variable y_k;

$\boldsymbol{\mu}_a^k = (\mu_a^{k,1},\ldots,\mu_a^{k,3})$ and $\boldsymbol{\mu}_Z^k = (\mu_Z^{k,1},\ldots,\mu_Z^{k,3})$ are the vectors of the fuzzy causes D, St, I for the variables a_k and $z_k(y_k)$;

$\boldsymbol{\mu}_v^k = (\mu_v^{k,1},\ldots,\mu_v^{k,3})$ and $\boldsymbol{\mu}_u = (\mu_u^1,\ldots,\mu_u^3)$ are the vectors of the fuzzy effects D, St, I for the variables v_k and u;

$\mathbf{H}_1^k = [\,h_1^{k,IJ}\,]$, $\mathbf{H}_2^k = [\,h_2^{k,LJ}\,]$ and $\mathbf{Q}_1^k = [\,q_1^{k,IJ}\,]$, $\mathbf{Q}_2^k = [\,q_2^{k,IJ}\,]$, $I,J = \overline{1,3}$, $L = \overline{1,2}$, are the primary fuzzy relational matrices "viewing time (t_1,t_2) – demand x_k" and "demand x_k and supply z_k – control action y_k";

$\mathbf{G}^k = [\,g^{k,IJ}\,]$, $I,J = \overline{1,3}$, are the primary fuzzy relational matrices "demand x_k – ad break-factor a_k";

$\mathbf{R}_1^k = [\,r_1^{k,IJ}\,]$, $\mathbf{R}_2^k = [\,r_2^{k,IJ}\,]$ and $\mathbf{W}^k = [\,w^{k,IJ}\,]$, $I,J = \overline{1,3}$, are the primary fuzzy relational matrices "supply $z_k(y_k)$ with the ad break-factor a_k – restored genre ratings v_k – rating of the channel u";

$\circ$ and $\circ,\cap$ are the operations of the simplified and extended max-min composition corresponding to the correlations f_a^k, f_u and f_x^k, f_y^k, f_v^k [22].

We use a bell-shaped membership function model of variable τ to arbitrary term T in the form [19, 20]:

Preprints (www.preprints.org) | NOT PEER-REVIEWED | Posted: 5 November 2018 doi:10.20944/preprints201811.0092.v1

Peer-reviewed version available at *Data* **2018**, *3*, 57; doi:10.3390/data3040057

$$\mu^T(\tau) = 1 \big/ (1 + ((\tau - \beta)/\sigma)^2),$$

where β is a coordinate of function maximum, $\mu^T(\beta) = 1$; σ is a parameter of concentration.

In this case, correlations (6)-(10) take the form:

- for content management

$$\boldsymbol{\mu}_x^k = f_x^k(t_1, t_2, p, \mathbf{H}_1^k, \mathbf{H}_2^k, \boldsymbol{\Psi}_t^1, \boldsymbol{\Psi}_t^2), \quad (11)$$

$$\boldsymbol{\mu}_y^k(y_k, \boldsymbol{\Psi}_y) = f_y^k(\boldsymbol{\mu}_x^k, z_k, \mathbf{Q}_1^k, \mathbf{Q}_2^k, \boldsymbol{\Psi}_z^k), \quad (12)$$

- for rating evaluation

$$\boldsymbol{\mu}_a^k = f_a^k(\boldsymbol{\mu}_x^k, \mathbf{G}^k), \quad (13)$$

$$\boldsymbol{\mu}_v^k = f_v^k(\boldsymbol{\mu}_Z^k, \boldsymbol{\mu}_a^k, \mathbf{R}_1^k, \mathbf{R}_2^k, \boldsymbol{\Psi}_z^k), \quad (14)$$

$$\boldsymbol{\mu}_u(u, \boldsymbol{\Psi}_u) = f_u(\boldsymbol{\mu}_v^1, ..., \boldsymbol{\mu}_v^n, \mathbf{W}^1, .., \mathbf{W}^n), \quad (15)$$

where $\boldsymbol{\Psi}_t^1 = (\beta_t^{1,1}, \sigma_t^{1,1}, ..., \beta_t^{1,3}, \sigma_t^{1,3})$, $\boldsymbol{\Psi}_t^2 = (\beta_t^{2,1}, \sigma_t^{2,1}, \beta_t^{2,2}, \sigma_t^{2,2})$ and $\boldsymbol{\Psi}_z^k = (\beta_z^{k,1}, \sigma_z^{k,1}, ..., \beta_z^{k,3}, \sigma_z^{k,3})$ are the vectors of parameters of the primary membership functions of the input variables t_1, t_2 and z_k;

$\boldsymbol{\Psi}_y^k = (\beta_y^{k,1}, \sigma_y^{k,1}, ..., \beta_y^{k,3}, \sigma_y^{k,3})$ and $\boldsymbol{\Psi}_u = (\beta_u^1, \sigma_u^1, ..., \beta_u^3, \sigma_u^3)$ are the vectors of parameters of the primary membership functions of the output variables y_k and u.

It is assumed that some training data sample can be obtained on the grounds of successful managerial decisions

$$\langle\ \hat{p},\ \hat{\mathbf{t}}_{kl}^p,\ \hat{z}_{kl}^p(\hat{\mathbf{t}}_{kl}^p, \hat{p} - 1),\ \hat{z}_{kl}^p(\hat{\mathbf{t}}_{kl}^p, \hat{p}),\ \hat{u}_{kl}^p(\hat{\mathbf{t}}_{kl}^p, \hat{p})\ \rangle,\ p = \overline{1, P},\ l = \overline{1, L_{pk}},$$

where P is the number of weeks in the data sample;

L_{pk} is the number of TV programs of the genre k in the weekly experiment number p;

$\hat{\mathbf{t}}_{kl}^p$ and $\hat{z}_{kl}^p$ are the control system state parameters in the experimental time slot number pkl;

$\hat{u}_{kl}^p$ is the TV rating in the experimental time slot $\hat{\mathbf{t}}_{kl}^p$.

The essence of the fuzzy model (11)-(15) tuning is as follows. It is necessary to find the relation matrices $\mathbf{H}_{1-2}^k$, $\mathbf{Q}_{1-2}^k$, $\mathbf{G}^k$, $\mathbf{R}_{1-2}^k$, $\mathbf{W}^k$ and the vectors of the membership functions parameters

Preprints (www.preprints.org) | NOT PEER-REVIEWED | Posted: 5 November 2018 doi:10.20944/preprints201811.0092.v1

Peer-reviewed version available at Data 2018, 3, 57; doi:10.3390/data3040057

$\mathbf{\Psi}_t^1$, $\mathbf{\Psi}_t^2$, $\mathbf{\Psi}_z^k$, $\mathbf{\Psi}_y^k$, $\mathbf{\Psi}_u$, which provide the minimum distance between theoretical and experimental data:

$$\sum_{p=1}^{P}\sum_{k=1}^{n}\sum_{l=1}^{L_{pk}}[f_u(\hat{p}, \hat{\mathbf{t}}_{kl}^{p}, \hat{z}_{kl}^{p}, \mathbf{H}_{l-2}^{k}, \mathbf{Q}_{l-2}^{k}, \mathbf{G}^{k}, \mathbf{R}_{l-2}^{k}, \mathbf{W}^{k}, \mathbf{\Psi}_t^{l-2}, \mathbf{\Psi}_z^{k}, \mathbf{\Psi}_y^{k}) - \hat{\mu}_u(\hat{u}_{kl}^{p}, \mathbf{\Psi}_u)]^2 = \min_{\mathbf{H},\mathbf{Q},\mathbf{G},\mathbf{R},\mathbf{W},\mathbf{\Psi}}. \quad (16)$$

We shall denote:

X_{kj} and Y_{kj}, $j=\overline{1,7}$, are the modified decision classes of the variables $x_k(\mathbf{t},p)$ and $y_k(\mathbf{t},p)$;

A_{kj}, V_{kj} and U_j, $j=\overline{1,7}$, are the modified decision classes of the variables $a_k(\mathbf{t},p)$, $v_k(\mathbf{t},p)$ and $u(\mathbf{t},p)$, respectively;

N_x^{kj} and N_y^{kj} are the numbers of composite rules in the classes X_{kj} and Y_{kj};

N_a^{kj}, N_v^{kj} and N_u^{j} are the numbers of composite rules in the classes A_{kj}, V_{kj} and U_j, respectively.

Given the output classes, the solution set of primary fuzzy relational equations (6)-(10) can be considered as the set of composite fuzzy rules [24, 25]:

- for content management

$$\bigcup_{i=1,N_x^{kj}}\left[\left[\underline{\mu}_t^{1,ij}, \overline{\mu}_t^{1,ij}\right] \cap \left[\underline{\mu}_t^{2,ij}, \overline{\mu}_t^{2,ij}\right]\right] \to x_k = X_{kj}; \quad (17)$$

$$\bigcup_{i=1,N_y^{kj}}\left[\left[\underline{\mu}_x^{k,ij}, \overline{\mu}_x^{k,ij}\right] \cap \left[\underline{\mu}_z^{k,ij}, \overline{\mu}_z^{k,ij}\right]\right] \to y_k = Y_{kj}; \quad (18)$$

- for rating evaluation

$$\bigcup_{i=1,N_a^{kj}}\left[\underline{\mu}_x^{k,ij}, \overline{\mu}_x^{k,ij}\right] \to a_k = A_{kj}; \quad (19)$$

$$\bigcup_{i=1,N_v^{kj}}\left[\left[\underline{\mu}_Z^{k,ij}, \overline{\mu}_Z^{k,ij}\right] \cap \left[\underline{\mu}_a^{k,ij}, \overline{\mu}_a^{k,ij}\right]\right] \to v_k = V_{kj}; \quad (20)$$

$$\bigcup_{i=1,N_u^{j}}\left[\left[\underline{\mu}_v^{1,ij}, \overline{\mu}_v^{1,ij}\right] \cup \ldots \cup \left[\underline{\mu}_v^{n,ij}, \overline{\mu}_v^{n,ij}\right]\right] \to u = U_j. \quad (21)$$

In (17)-(21), the fuzzy solution vectors are presented in the form of the vectors of the lower and upper bounds of the fuzzy causes significance measures, where

Preprints (www.preprints.org) | NOT PEER-REVIEWED | Posted: 5 November 2018 doi:10.20944/preprints201811.0092.v1

Peer-reviewed version available at *Data* **2018**, *3*, 57; doi:10.3390/data3040057

$\underline{\boldsymbol{\mu}}_t^{1,ij}=(\underline{\mu}_t^{11,ij},...,\underline{\mu}_t^{13,ij})$, $\overline{\boldsymbol{\mu}}_t^{1,ij}=(\overline{\boldsymbol{\mu}}_t^{11,ij},...,\overline{\boldsymbol{\mu}}_t^{13,ij})$ and $\underline{\boldsymbol{\mu}}_t^{2,ij}=(\underline{\mu}_t^{21,ij},\underline{\mu}_t^{22,ij})$, $\overline{\boldsymbol{\mu}}_t^{2,ij}=(\overline{\boldsymbol{\mu}}_t^{21,ij},\overline{\boldsymbol{\mu}}_t^{22,ij})$ are the lower and upper fuzzy solution vectors for the variables t_1 and t_2;

$\underline{\boldsymbol{\mu}}_x^{k,ij}=(\underline{\mu}_x^{k1,ij},...,\underline{\mu}_x^{k3,ij})$, $\overline{\boldsymbol{\mu}}_x^{k,ij}=(\overline{\boldsymbol{\mu}}_x^{k1,ij},...,\overline{\boldsymbol{\mu}}_x^{k3,ij})$ and $\underline{\boldsymbol{\mu}}_z^{k,ij}=(\underline{\mu}_z^{k1,ij},...,\underline{\mu}_z^{k3,ij})$, $\overline{\boldsymbol{\mu}}_z^{k,ij}=(\overline{\boldsymbol{\mu}}_z^{k1,ij},...,\overline{\boldsymbol{\mu}}_z^{k3,ij})$ are the lower and upper fuzzy solution vectors for the variables x_k and z_k;

$\underline{\boldsymbol{\mu}}_Z^{k,ij}=(\underline{\mu}_Z^{k1,ij},...,\underline{\mu}_Z^{k3,ij})$, $\overline{\boldsymbol{\mu}}_Z^{k,ij}=(\overline{\boldsymbol{\mu}}_Z^{k1,ij},...,\overline{\boldsymbol{\mu}}_Z^{k3,ij})$ and $\underline{\boldsymbol{\mu}}_a^{k,ij}=(\underline{\mu}_a^{k1,ij},...,\underline{\mu}_a^{k3,ij})$, $\overline{\boldsymbol{\mu}}_a^{k,ij}=(\overline{\boldsymbol{\mu}}_a^{k1,ij},...,\overline{\boldsymbol{\mu}}_a^{k3,ij})$ are the lower and upper fuzzy solution vectors for the variables $z_k\,(y_k)$ and a_k;

$\underline{\boldsymbol{\mu}}_v^{k,ij}=(\underline{\mu}_v^{k1,ij},...,\underline{\mu}_v^{k3,ij})$, $\overline{\boldsymbol{\mu}}_v^{k,ij}=(\overline{\boldsymbol{\mu}}_v^{k1,ij},...,\overline{\boldsymbol{\mu}}_v^{k3,ij})$ are the lower and upper fuzzy solution vectors for the variables v_k.

Given the primary fuzzy model (6), (7) and the output classes X_{kj} and Y_{kj}, $j=\overline{1,7}$, the problem of tuning the composite fuzzy model for content management is formulated as follows [24–27]. For each output class X_{kj} and Y_{kj}, $j=\overline{1,7}$, the solution set (17), (18) should be found which provides the least distance between observed and model fuzzy effects vectors in correlations (6), (7):

$$[f_y^k(\boldsymbol{\mu}_x^k,\boldsymbol{\mu}_z^k,\mathbf{Q}_{l-2}^k)-\boldsymbol{\mu}_y^k(Y_{kj})]^2=\min_{\boldsymbol{\mu}_x^k,\boldsymbol{\mu}_z^k}, \tag{22}$$

$$[f_x^k(\boldsymbol{\mu}_t^1,\boldsymbol{\mu}_t^2,\mathbf{H}_{l-2}^k)-\boldsymbol{\mu}_x^k(X_{kj})]^2=\min_{\boldsymbol{\mu}_t^1,\boldsymbol{\mu}_t^2}. \tag{23}$$

Given the primary fuzzy model (8)-(10) and the output classes A_{kj}, V_{kj} and U_j, $j=\overline{1,7}$, the problem of tuning the composite fuzzy model for rating evaluation is formulated as follows [24–27]. For each output class A_{kj}, V_{kj} and U_j, $j=\overline{1,7}$, the solution set (19)-(21) should be found which provides the least distance between observed and model fuzzy effects vectors in correlations (8)-(10):

$$[f_u(\boldsymbol{\mu}_v^1,...,\boldsymbol{\mu}_v^n,\mathbf{W}^1,...,\mathbf{W}^n)-\boldsymbol{\mu}_u(U_j)]^2=\min_{\boldsymbol{\mu}_v^1,...,\boldsymbol{\mu}_v^n}, \tag{24}$$

$$[f_v^k(\boldsymbol{\mu}_Z^k,\boldsymbol{\mu}_a^k,\mathbf{R}_{l-2}^k)-\boldsymbol{\mu}_v^k(V_{kj})]^2=\min_{\boldsymbol{\mu}_Z^k,\boldsymbol{\mu}_a^k}, \tag{25}$$

$$[f_a^k(\boldsymbol{\mu}_x^k,\mathbf{G}^k)-\boldsymbol{\mu}_a^k(A_{kj})]^2=\min_{\boldsymbol{\mu}_x^k}. \tag{26}$$

The genetic-neuro algorithm is used for solving the optimization problems (16), (22)–(26) of tuning the primary fuzzy model and rule-based solutions of primary fuzzy relational equations [28, 29].

Preprints (www.preprints.org) | NOT PEER-REVIEWED | Posted: 5 November 2018 doi:10.20944/preprints201811.0092.v1

Peer-reviewed version available at *Data* **2018**, *3*, 57; doi:10.3390/data3040057

3.3. Solving Fuzzy Relational Equations

Let us consider the construction of the composite fuzzy rules (17)-(21). The primary system of fuzzy relational equations (6)-(10) has the form:

- for content management

$$\begin{aligned} \mu_x^{k,1} &= ((\mu_t^{1,1} \wedge h_1^{1,11}) \vee \ldots \vee (\mu_t^{1,3} \wedge h_1^{1,31})) \wedge ((\mu_t^{2,1} \wedge h_2^{2,11}) \vee (\mu_t^{2,2} \wedge h_2^{2,21})); \\ &\ldots \\ \mu_x^{k,3} &= ((\mu_t^{1,1} \wedge h_1^{1,13}) \vee \ldots \vee (\mu_t^{1,3} \wedge h_1^{1,33})) \wedge ((\mu_t^{2,1} \wedge h_2^{2,13}) \vee (\mu_t^{2,2} \wedge h_2^{2,23})); \end{aligned} \quad (27)$$

$$\begin{aligned} \mu_y^{k,1} &= ((\mu_x^{k,1} \wedge q_1^{k,11}) \vee \ldots \vee (\mu_x^{k,3} \wedge q_1^{k,31})) \wedge ((\mu_z^{k,1} \wedge q_2^{k,11}) \vee \ldots \vee (\mu_z^{k,3} \wedge q_2^{k,31})); \\ &\ldots \\ \mu_y^{k,3} &= ((\mu_x^{k,1} \wedge q_1^{k,13}) \vee \ldots \vee (\mu_x^{k,3} \wedge q_1^{k,33})) \wedge ((\mu_z^{k,1} \wedge q_2^{k,13}) \vee \ldots \vee (\mu_z^{k,3} \wedge q_2^{k,33})); \end{aligned} \quad (28)$$

- for rating evaluation

$$\begin{aligned} \mu_a^{k,1} &= (\mu_x^{k,1} \vee g^{k,11}) \vee \ldots \vee (\mu_x^{k,3} \vee g^{k,31}); \\ &\ldots \\ \mu_a^{k,3} &= (\mu_x^{k,1} \vee g^{k,13}) \vee \ldots \vee (\mu_x^{k,3} \vee g^{k,33}); \end{aligned} \quad (29)$$

$$\begin{aligned} \mu_v^{k,1} &= ((\mu_Z^{k,1} \wedge r_1^{k,11}) \vee \ldots \vee (\mu_Z^3 \wedge r_1^{k,31})) \wedge ((\mu_a^{k,1} \wedge r_2^{k,11}) \vee \ldots \vee (\mu_a^{k,3} \wedge r_2^{k,31})); \\ &\ldots \\ \mu_v^{k,3} &= ((\mu_Z^{k,1} \wedge r_1^{k,13}) \vee \ldots \vee (\mu_Z^{k,3} \wedge r_1^{k,33})) \wedge ((\mu_a^{k,1} \wedge r_2^{k,13}) \vee \ldots \vee (\mu_a^{k,3} \wedge r_2^{k,33})); \end{aligned} \quad (30)$$

$$\begin{aligned} \mu_u^1 &= ((\mu_v^{1,1} \vee w^{1,11}) \vee \ldots \vee (\mu_v^{1,3} \vee w^{1,31})) \vee \ldots \vee ((\mu_v^{n,1} \vee w^{n,11}) \vee \ldots \vee (\mu_v^{n,3} \vee w^{n,31})); \\ &\ldots \\ \mu_u^3 &= ((\mu_v^{1,1} \vee w^{1,13}) \vee \ldots \vee (\mu_v^{1,3} \vee w^{1,33})) \vee \ldots \vee ((\mu_v^{n,1} \vee w^{n,13}) \vee \ldots \vee (\mu_v^{n,3} \vee w^{n,33})). \end{aligned} \quad (31)$$

In (27), (29) and (31), the trend fuzzy relations are tuned for each content category. In (28) and (30), the trend fuzzy relations are tuned regardless of the genre. Evaluation of the ratings of TV programs in the channel broadcasting network is carried out with the help of the authors' monitoring system [34]. The training sample includes data from 2015 to 2018.

The results of the primary fuzzy model tuning are presented in Appendix A. Parameters of the membership functions for the input and output primary fuzzy terms are presented in Tables A1, A2. The primary fuzzy relational matrices after tuning are presented in Tables A3-A7.

The results of the composite fuzzy model tuning are presented in Appendix B. In Tables B1-B5, the sets of solutions in the form of the fuzzy causes vectors correspond to the fuzzy effects vectors obtained for the given decision classes. Bounds of the decision classes U_j and Y_{kj}, $j=\overline{1,7}$, were defined as follows:

$$[\underline{u},\overline{u}] = \underbrace{[0,3)}_{shD} \cup \underbrace{[3,6)}_{mD} \cup \underbrace{[6,9)}_{wD} \cup \underbrace{[9,11)}_{St} \cup \underbrace{[11,13)}_{wI} \cup \underbrace{[13,17)}_{mI} \cup \underbrace{[17,20]}_{shI},$$

$$[\underline{y}_k, \overline{y}_k] = \underbrace{[-10,-7)}_{shD} \cup \underbrace{[-7,-3)}_{mD} \cup \underbrace{[-3,-1)}_{wD} \cup \underbrace{[-1,1)}_{N} \cup \underbrace{[1,3)}_{wI} \cup \underbrace{[3,7)}_{mI} \cup \underbrace{[7,10]}_{shI}.$$

For the given bounds of decision classes, the fuzzy effects vectors $\boldsymbol{\mu}_u(U_j)$ and $\boldsymbol{\mu}_y^k(Y_{kj})$ were defined with the help of the primary membership functions of the variables u and y_k (Table A2). For the decision classes V_{kj}, A_{kj} and X_{kj}, $j=\overline{1,7}$, the fuzzy effects vectors $\boldsymbol{\mu}_v^k(V_{kj})$, $\boldsymbol{\mu}_a^k(A_{kj})$ and $\boldsymbol{\mu}_x^k(X_{kj})$ were defined by the fuzzy solution vectors obtained for the higher levels of the hierarchical tree of logic inference.

The sets of interval rules corresponding to the sets of solutions from Tables B1-B5 are presented in Tables 6-10. Linguistic interpretation of the obtained solutions allows generating the hierarchical composite fuzzy rules. For the simplified and extended composition laws [22], the sets of solutions are interpreted in the form of the "single input – single output" (Tables 6, 8) and "multiple inputs – single output" (Tables 7, 9, 10) rules [28, 29]. The lower and upper bounds of the interval rules were obtained with the help of the primary membership functions of the variables t_1, t_2 and z_k (Table A1).

Table 6. Composite fuzzy rules for the TV rating

IF (or)			THEN
$v_1(\mathbf{t},p)$	$v_2(\mathbf{t},p)$	$v_3(\mathbf{t},p)$	$u(\mathbf{t},p)$
0–2.0, shD	0–4.0, shD	0–9.0, shD–wD	shD
2.0–4.4, shD-mD	3.8–4.4, mD	0–9.0, shD–wD	mD
4.4–7.4, mD-wD	4.4–7.4, mD-wD	6.2–11.2, wD-St	wD
6.8–9.0, wD	7.6–10.0, wD-St	6.2–11.2, wD-St	St
8.4–12.9, St-wI	10.2–12.9, wI	8.8–14.0, St-wI	wI
10.8–16.7, wI-mI	12.4–15.6, wI-mI	10.8–15.6, wI-mI	mI
16.7–20, shI	15.6–20, mI-shI	15.6–20, mI-shI	shI

 doi:10.20944/preprints201811.0092.v1

Peer-reviewed version available at *Data* **2018**, *3*, 57; doi:10.3390/data3040057

Table 7. Composite fuzzy rules for the restored genre ratings

IF (and)		THEN
$z_k(y_k(\mathbf{t},p))$	$a_k(\mathbf{t},p)$	$v_k(\mathbf{t},p)$
0–1.2	shD	shD
1.2–2.2	shD	mD
0–2.2	mD	
2.2–3.7	mD–wD	wD
3.5–4.4	wD–St	
2.9–4.4	St–wI	St
3.7–5.0	wD–wI	
5.0–6.9	wD–St	
5.1–6.9	wI–mI	wI
5.9–7.7	St–wI	
6.9–7.9	wI–mI	mI
5.4–7.6	mI–shI	
7.9–10	shI	shI

Table 8. Composite fuzzy rules for the ad break-factor

IF (or)			THEN
$x_1(\mathbf{t},p)$	$x_2(\mathbf{t},p)$	$x_3(\mathbf{t},p)$	$a_k(\mathbf{t},p)$
shD–mD	shD	shD	shD
mD	mD	mD	mD
mD–wD	mD–wD	mD–wD	wD
wD–St	wD–wI	St–wI	St
wI–mI	wI	wI–mI	wI
St–mI	mI	wI–mI	mI
shI	shI	shI	shI

Table 9. Composite fuzzy rules for the control action

IF (and)		THEN
$x_k(\mathbf{t},p)$	$z_k(\mathbf{t},p-1)$	$y_k(\mathbf{t},p)$
shD	8.3–10	shD
mD	7.6–10	mD
mD–shD	6.1–7.6	
mD–shD	3.6–5.9	
wD–wI	7.6–10	
mD–shD	1.8–2.6	wD
wD–wI	5.9–6.2	
wD	3.4–6.2	
mI	7.1–10	

Peer-reviewed version available at *Data* **2018**, *3*, 57; doi:10.3390/data3040057

shD St shI	0–1.8 3.8–5.0 7.9–10	N
mD wD–wI wI mI–shI	0–2.1 3.4–3.5 3.50–5.8 7.4–7.9	wI
wD–wI mI–shI mI mI–shI	0–1.9 3.4–5.3 0–1.9 1.9–2.8	mI
shI	0–1.4	shI

Table 10. Composite fuzzy rules for the viewers' demand

IF (and)						THEN
k=1		k=2		k=3		
t_1	t_2	t_1	t_2	t_1	t_2	$x_k(\mathbf{t},p)$
12–14	1–5	5–8	1–5	11-14	1-5	shD
10–12 14–16 11–17	1–5 1–5 6,7	5–8 8–11	6, 7 1–5	10-12	1-5	mD
5–7 18–20 22–24	1–5 6, 7 1–5	8–10 10–12	6, 7 1–5	8-10	1-7	wD
7–8 19–21 21–22	1–7 6, 7 1–7	12–16	1–7	5-8 12-16 14-16	1-7 6, 7 1-5	St
8–11 16–18	6, 7 1–7	16–18	1–7	9-12 16-18	6, 7 1-7	wI
8–10 18–20	1–5 1–5	17–19 18–24	6, 7 1–5	17-20 18-24	1-7 1-5	mI
20–21	1–5	18–24	6, 7	19-24	6, 7	shI

3.4. Example of the TV Rating Control: Construction of the Weekly TV Program

The values ⟨viewers' demand $\hat{x}_k(\mathbf{t},p)$, supply before and after control $\hat{z}_k(\mathbf{t},p-1)$, $\hat{z}_k(\mathbf{t},p)$, control action $\hat{y}_k(\mathbf{t},p)=\hat{z}_k(\mathbf{t},p)-\hat{z}_k(\mathbf{t},p-1)$, rating $\hat{u}(\mathbf{t},p)$ ⟩, corresponding to the experienced manager actions were taken as the training data sample. In this case, the TV rating was maintained at a consistently high level, and the unmet viewers' demand was reduced to a minimum. The unmet demand after control in each genre category can be defined as $\Delta_k(\mathbf{t},p)=x_k(\mathbf{t},p)-z_k(\mathbf{t},p)$. It is supposed, that for the balanced demand $x_k(\mathbf{t},p)=z_k(\mathbf{t},p)$. The experimental values $\hat{x}_k(\mathbf{t},p)$ for each genre category can be obtained from Table 10. The experimental values $\hat{z}_k(\mathbf{t},p-1)$, $\hat{z}_k(\mathbf{t},p)$ and $\hat{u}(\mathbf{t},p)$ were determined on the basis of the weekly top 20 rating [30].

Preprints (www.preprints.org) | NOT PEER-REVIEWED | Posted: 5 November 2018 doi:10.20944/preprints201811.0092.v1

Peer-reviewed version available at *Data* **2018**, *3*, 57; doi:10.3390/data3040057

The training sample fragment is presented in Tables 11, 12 in the form of the weekly TV program constructed for weekdays and weekends from 1.10.2018 to 7.10.2018. Media planning is accompanied with the analysis of the main television indices. Tables 11, 12 reflect the dynamics of the demand and supply change for each genre during the day. The experimental demand $\hat{x}_k(\mathbf{t},p)$ and supply $\hat{z}_k(\mathbf{t},p-1)$ are balanced by the model control action $y_k(\mathbf{t},p)$. To balance the demand, the priority content category is chosen for each time slot. The priority genre k is in high demand compared to other categories. The obtained pairs "time slot **t** – imdb-rating $z_k(\mathbf{t},p)$ after control" represent the broadcast grid of the forthcoming week. The characteristics of the generated content are evaluated by the ad break-factor $a_k(\mathbf{t},p)$. Stability of the content to the ad break-factor guarantees the high television ratings $v_k(\mathbf{t},p)$. Planning without alternatives is based on the past behavior of viewers. In this case, monitoring results depict the rating restored after the ad unit, i.e. $u(\mathbf{t},p)=v_k(\mathbf{t},p)$. In the case of the alternative propositions $v_k(\mathbf{t},p)$, the preliminary selection is based on users preferences. Finally, the model $u(\mathbf{t},p)$ and experimental $\hat{u}(\mathbf{t},p)$ ratings are compared for each time slot.

It is shown from Tables 11, 12, that the weekly top 20 list covers each time slot. For the political genre, the offered programs have balanced the viewers' demand. On weekdays from 18 to 23 hours, some popular serials have been offered instead of the entertainment programs. On weekends, the demand for the genre of television serials from 18 to 23 hours has been satisfied with the programs of the sports and entertainment genre.

Table 11. Weekdays timetable

<table>
<tr><th rowspan="2">Time slot</th><th colspan="8">Television indices for genre k</th></tr>
<tr><th>$\hat{x}_k(\mathbf{t},p)$</th><th>$\Delta_k(\mathbf{t},p)$</th><th>$\hat{z}_k(\mathbf{t},p-1)$</th><th>$y_k(\mathbf{t},p)$</th><th>$z_k(\mathbf{t},p)$</th><th>$a_k(\mathbf{t},p)$</th><th>$v_k(\mathbf{t},p)$ / $u(\mathbf{t},p)$</th><th>$\hat{u}(\mathbf{t},p)$</th></tr>
<tr><td>7-8</td><td>1, 3, St</td><td>2, shD</td><td rowspan="3">1, 3, 5.6</td><td rowspan="3">0</td><td rowspan="3">1, 3, 5.6</td><td rowspan="3">1, 3, 0.99</td><td rowspan="3">1, 3, 14.0</td><td rowspan="3">1, 3, 15.0</td></tr>
<tr><td>8-9</td><td rowspan="2">1, mI;
3, wD</td><td rowspan="2">2, mD</td></tr>
<tr><td>9-10</td></tr>
<tr><td>10-11</td><td rowspan="2">2, wD</td><td rowspan="2">1, 3, mD</td><td rowspan="2">2, 4.5</td><td rowspan="2">0</td><td rowspan="2">2, 4.5</td><td rowspan="2">2, 0.84</td><td rowspan="2">2, 5.5</td><td rowspan="2">2, 4.6</td></tr>
<tr><td>11-12</td></tr>
<tr><td>12-13</td><td rowspan="2">1, 2, St</td><td rowspan="2">3, shD</td><td>1, 3.9</td><td>0</td><td>1, 3.9</td><td>1, 0.89</td><td>1, 4.3</td><td>1, 4.5</td></tr>
<tr><td>13-14</td><td rowspan="3">2, 4.8</td><td>0</td><td>2, 4.8</td><td>2, 0.85</td><td>2, 9.0</td><td>2, 7.8</td></tr>
<tr><td>14-15</td><td rowspan="2">2, 3, St</td><td rowspan="2">1, mD</td><td rowspan="2">2, +0.7</td><td rowspan="2">2, 5.5</td><td rowspan="2">2, 0.88</td><td rowspan="2">2, 11.0</td><td rowspan="2">2, 9.5</td></tr>
<tr><td>15-16</td></tr>
<tr><td>16-17</td><td rowspan="2">2, 3 wI</td><td rowspan="2">1, wI</td><td>2, 5.9</td><td>2, +0.5</td><td>2, 6.4</td><td>2, 0.89</td><td>2, 12.9</td><td>2, 12.1</td></tr>
<tr><td>17-18</td><td>1, 6.2</td><td>0</td><td>1, 6.2</td><td>1, 0.85</td><td>1, 12.5</td><td>1, 13.0</td></tr>
<tr><td>18-19</td><td rowspan="2">2, 3, mI</td><td rowspan="2">1, mI</td><td rowspan="2">2, 8.6</td><td rowspan="2">0</td><td rowspan="2">2, 8.6</td><td rowspan="2">2, 0.99</td><td rowspan="2">2, 16.5</td><td rowspan="2">2, 14.0</td></tr>
<tr><td>19-20</td></tr>
<tr><td>20-21</td><td>1, shI</td><td>2, 3, mI</td><td>1, 8.3</td><td>0</td><td>1, 8.3</td><td>1, 0.98</td><td>1, 12.0</td><td>1, 10.5</td></tr>
<tr><td>21-22</td><td>2, 3, mI</td><td>1, St</td><td rowspan="2">2, 6.7</td><td>2, +1.3</td><td>2, 8.0</td><td>2, 0.87</td><td>2, 11.5</td><td>2, 7.5</td></tr>
<tr><td>22-23</td><td rowspan="2">2, 3, mI</td><td rowspan="2">1, wD</td><td rowspan="2">2, +1.3 or
3, +8.1</td><td rowspan="2">2, 7.4 or
3, 8.1</td><td rowspan="2">2, 0.86 or
3, 0.72</td><td rowspan="2">2, 9.0 or
3, 8.5</td><td rowspan="2">2, 6.8</td></tr>
<tr><td>23-24</td><td>2, 6.1</td></tr>
</table>

Preprints (www.preprints.org) | NOT PEER-REVIEWED | Posted: 5 November 2018 doi:10.20944/preprints201811.0092.v1

Peer-reviewed version available at Data 2018, 3, 57; doi:10.3390/data3040057

Table 12. Weekends timetable

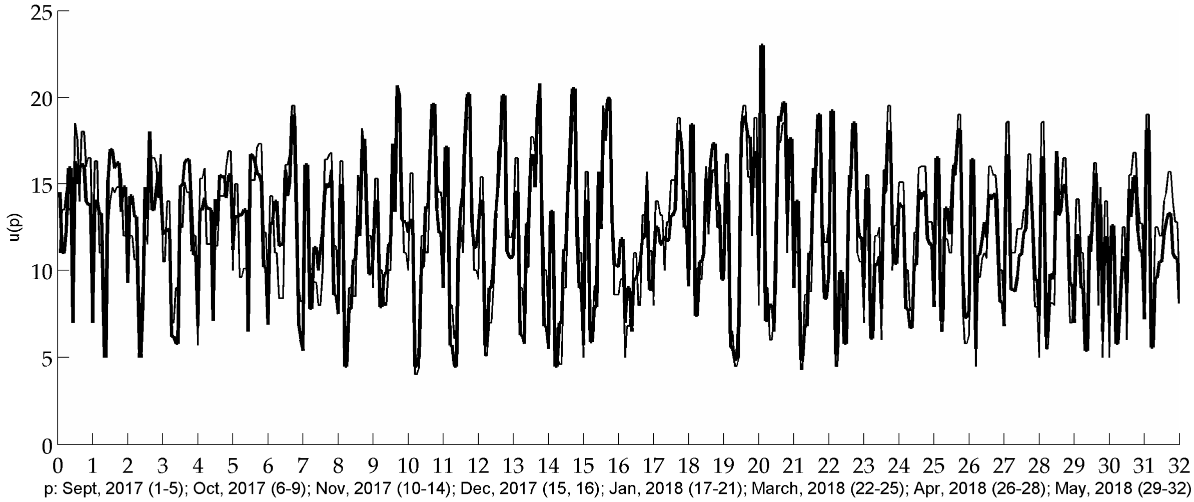
<table>
<tr><th rowspan="2">Time slot</th><th colspan="8">Television indices for genre k</th></tr>
<tr><th>$\hat{x}_k(\mathbf{t},p)$</th><th>$\Delta_k(\mathbf{t},p)$</th><th>$\hat{z}_k(\mathbf{t},p-1)$</th><th>$y_k(\mathbf{t},p)$</th><th>$z_k(\mathbf{t},p)$</th><th>$a_k(\mathbf{t},p)$</th><th>$v_k(\mathbf{t},p)$ / $u(\mathbf{t},p)$</th><th>$\hat{u}(\mathbf{t},p)$</th></tr>
<tr><td>7-8</td><td>1, 3, St</td><td>2, mD</td><td rowspan="2">1, 3, 4.4</td><td rowspan="2">0</td><td rowspan="2">1, 3, 4.4</td><td rowspan="2">1, 3, 0.85</td><td rowspan="2">1, 3, 5.5</td><td rowspan="2">1, 3, 4.5</td></tr>
<tr><td>8-9</td><td rowspan="2">1, wI; 3, wD</td><td rowspan="2">2, wD</td></tr>
<tr><td>9-10</td><td>1, 3, 3.1</td><td>1, 3, +1.9</td><td>1, 3, 5.0</td><td>1, 3, 0.90</td><td>1, 3, 10.0</td><td>1, 3, 8.1</td></tr>
<tr><td>10-11</td><td>1, 3, wI</td><td>2, wD</td><td rowspan="2">3, 6.5</td><td rowspan="2">2, +4.8 or 3, 0</td><td rowspan="2">2, 4.8 or 3, 6.5</td><td rowspan="2">2, 0.81 or 3, 0.84</td><td rowspan="2">2, 7.2 or 3, 8.5</td><td rowspan="2">3, 6.1</td></tr>
<tr><td>11-12</td><td>2, wD; 3, wI</td><td>1, mD</td></tr>
<tr><td>12-13</td><td rowspan="4">2, 3, St</td><td rowspan="4">1, mD</td><td rowspan="4">2, 5.8</td><td rowspan="2">2, -0.3</td><td rowspan="2">2, 5.5</td><td rowspan="2">2, 0.79</td><td rowspan="2">2, 11.0</td><td rowspan="2">2, 9.0</td></tr>
<tr><td>13-14</td></tr>
<tr><td>14-15</td><td rowspan="2">2, +0.4</td><td rowspan="2">2, 6.2</td><td rowspan="2">2, 0.81</td><td rowspan="2">2, 11.5</td><td rowspan="2">2, 8.6</td></tr>
<tr><td>15-16</td></tr>
<tr><td>16-17</td><td>2, 3, wI</td><td>1, mD</td><td rowspan="2">2, 6.9</td><td rowspan="2">2, +0.5</td><td rowspan="2">2, 7.4</td><td rowspan="2">2, 0.75</td><td rowspan="2">2, 8.2</td><td rowspan="2">2, 5.5</td></tr>
<tr><td>17-18</td><td>2, wI</td><td>1, 3, wI</td></tr>
<tr><td>18-19</td><td>2, 3 mI</td><td>1, wD</td><td rowspan="2">3, 8.8</td><td rowspan="2">2, +9.1 or 3, 0</td><td rowspan="2">2, 9.1 or 3, 8.8</td><td rowspan="2">2, 0.82 or 3, 0.90</td><td rowspan="2">2, 12.5 or 3, 12.9</td><td rowspan="2">3, 8.2</td></tr>
<tr><td>19-20</td><td>2, shI; 3, mI</td><td>1, wD</td></tr>
<tr><td>20-21</td><td rowspan="2">1, St; 2, 3, shI</td><td>2, 3, shI</td><td>1, 6.7</td><td>0</td><td>1, 6.7</td><td>1, 0.90</td><td>1, 8.3</td><td>1, 7.6</td></tr>
<tr><td>21-22</td><td>1, St</td><td>3, 9.1</td><td rowspan="2">2, +9.3 or 3, 0</td><td rowspan="2">2, 9.3 or 3, 9.1</td><td rowspan="2">2, 0.95 or 3, 0.99</td><td rowspan="2">2, 12.0 or 3, 12.2</td><td rowspan="2">3, 8.6</td></tr>
<tr><td>22-23</td><td rowspan="2">2, 3, shI</td><td rowspan="2">1, wD</td><td rowspan="2">3, 8.7</td></tr>
<tr><td>23-24</td><td>0</td><td>3, 8.7</td><td>3, 0.79</td><td>3, 9.0</td><td>3, 5.6</td></tr>
</table>

Comparison of the model and experimental ratings for $p \in [1, 32]$ weeks is shown in Figure 1. Figure 1 depicts the dynamics of the average weekly rating change at the level of each air-hour on weekdays and weekends from autumn 2017 to spring 2018. When compiling the average weekly rating, the time range is $t_1 \in [8, 23]$ hours, since the programs in the range $t_1 \in [0, 7]$ do not fall into the weekly top 20 rating.

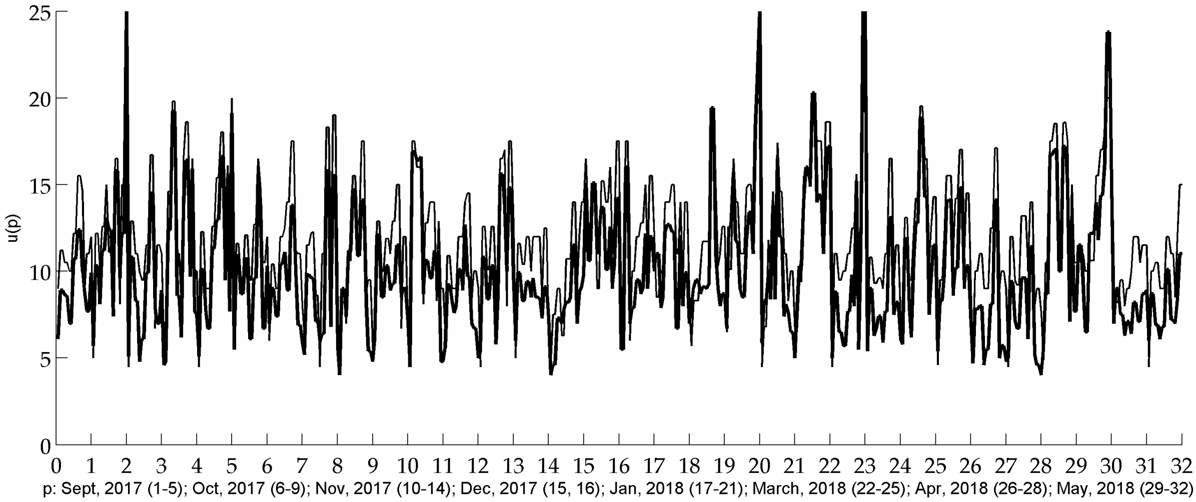
The fuzzy control model ensures the correctness of rating evaluation at the level of RMSE=1.88 for weekdays; RMSE=2.54 for weekends. On weekdays, the TV ratings are less sensitive to the multichannel environment. The ratings are sufficiently high and the evaluation error decreases. On weekends, the multichannel environment influences the TV ratings significantly. The ratings are unstable and the evaluation error increases.

doi:10.20944/preprints201811.0092.v1

Peer-reviewed version available at Data 2018, 3, 57; doi:10.3390/data3040057



(**a**)



(**b**)

Figure 1. The dynamics of the average weekly TV rating change for the model (----) and experimental (——) control action: (**a**) on weekdays; (**b**) on weekends.

4. Effectiveness Estimation of the Hybrid Approach

The papers [19, 20] proposed methods of semantic training the linguistically modified knowledge bases in the problems of fuzzy resources control. The given method simplifies the process of tuning the modified fuzzy knowledge base by solving the primary system of fuzzy relational equations. The effectiveness estimates of the hybrid approach proposed are given below.

We shall denote:

n is the number of input parameters (genres);

T and M are the numbers of input and output primary fuzzy terms;

Z is the number of composite fuzzy rules.

Candidate rule generation corresponds to the construction of a zero option of the timetable. In semantic training, candidate rule generation requires solving the optimization problem with 2nZ variables for boundaries of interval rules [19, 20]. Application of the hybrid approach allows reducing the number of tuning parameters by solving Z optimization problems for 2T boundaries of significance measures [24–27]. Rule generator tuning is the optimization problem with 2T+2M+TM variables for the trend relational matrix and membership functions parameters.

Selection, that is, finding the best configuration of zero option terms and rules, corresponds to the granulation of the television time. As a result, the broadcast grid can be represented in the form of the time slots and the granulated ratings of the content.

In semantic training, selection requires solving the optimization problem with nZ variables. A term selection sign with the possibility of merging the similar terms, as well as the degree of the rule relevance are subject to tuning [19, 20]. In the case of Z solutions of the trend system of equations, selection is reduced to maintaining the level of detail and density of coverage. Application of the hybrid approach reduces the number of tuning parameters by solving Z optimization problems for T modified terms in each rule [24–27].

The problem of TV rating control is reduced to the parallel programming of the television time for six genres (news and analytics, TV serials, documentary projects, programs for children, sports, entertainment). The permissible value of the planning time-frame is 1 hour. The time of tuning the fuzzy control model according to the method [19, 20] is 1 hour 20 min, which exceeds the planning time-frame (Intel Core i5 LGA1151 3.5 GHz processor). The tuning time for this method is 45 min, which allows media planning at the level of each air-hour.

5. Conclusions

1. The fuzzy model for retaining the TV rating is proposed in the framework of fuzzy resources control. The demand-supply trends are described by the primary fuzzy knowledge bases, where the increase or decrease of the television indices is described by the primary fuzzy terms. The refined fuzzy model is built using the linguistic modifiers of the primary fuzzy terms. The time factors, content and advertisement attributes are taken into account to balance the demand and supply. The fuzzy model of the demand allows generating item and timing recommendations simultaneously. The fuzzy model of the supply provides restoration of the ratings in the multichannel environment.

2. The method of expert recommendation systems construction for TV domain is proposed. TV experts define the primary fuzzy relational matrices. Automated media planning is carried out by solving the primary system of fuzzy relational equations. The granulated television time is determined by the rule-based solution set. The program attributes for each time slot are determined by significance measures of the primary fuzzy terms. The recommendation accuracy is achieved through the complete rule-based solution set. Rule set refinement by solving fuzzy relational equations allows avoiding labor-intensive procedures for the generation and selection of expert rules. Generation of the weekly TV program in the form of the granular solutions provides the decrease of the computational costs needed for the programming of the television time.

Supplementary Materials: are not submitted.

Author Contributions: conceptualization, Azarov, O. and Krupelnitsky, L.; methodology, Azarov, O., Krupelnitsky, L. and Rakytyanska, H.; software, Krupelnitsky, L. and Rakytyanska, H.; validation, Azarov, O., Krupelnitsky, L. and Rakytyanska, H.; formal analysis, Rakytyanska, H.; investigation, Krupelnitsky, L. and Rakytyanska, H.; resources, Krupelnitsky, L.; data curation, Krupelnitsky, L.; writing—original draft preparation, Rakytyanska, H.; writing—review and editing, Rakytyanska, H.; visualization, Krupelnitsky, L. and Rakytyanska, H.; supervision, Azarov, O.; project administration, Azarov, O.; funding acquisition, Azarov, O. and Krupelnitsky, L.

Funding: This research received no external funding.

Peer-reviewed version available at *Data* **2018**, *3*, 57; doi:10.3390/data3040057

Acknowledgments: The paper was prepared within the 58–D–369 "Technologies of the construction of intelligent analog-digital systems for monitoring and analysis of multimedia information" project.

Conflicts of Interest: The authors declare no conflict of interest. The funders had no role in the design of the study; in the collection, analyses, or interpretation of data; in the writing of the manuscript, or in the decision to publish the results.

Appendix A

Results of the Primary Fuzzy Model Tuning

Table A1. Parameters of the membership functions for the input primary fuzzy terms

Parameter	t_1			t_2		z_k		
	M	A	Ev	Wd	We	D	St	I
β	5	14	22	1	6	0.51	4.43	9.12
σ	3.92	3.19	3.75	4.52	0.94	2.67	1.28	2.54

Table A2. Parameters of the membership functions for the output primary fuzzy terms

Parameter	y_k			u		
	D	N	I	D	St	I
β	-9.53	0.41	9.60	2.14	9.22	16.70
σ	5.15	2.76	4.89	3.70	2.56	4.39

Table A3. Primary fuzzy relations "viewing time - demand" after tuning

IF		**THEN** $x_1(\mathbf{t},p)$			**THEN** $x_2(\mathbf{t},p)$			**THEN** $x_3(\mathbf{t},p)$		
		D	St	I	D	St	I	D	St	I
t_1	M	0.11	0.75	0.67	0.64	0.50	0.16	0.35	0.65	0.48
	A	0.79	0.62	0.54	0.22	0.75	0.51	0.59	0.82	0.67
	Ev	0.10	0.51	0.80	0.14	0.83	1.0	0.18	0.77	0.94
t_2	Wd	0.80	0.91	1.0	0.61	0.85	0.68	0.64	0.89	0.67
	We	0.56	0.70	0.59	0.27	0.92	1.0	0.19	0.86	1.0

Table A4. Primary fuzzy relations "demand and supply – control action" after tuning

IF		**THEN** $y_k(\mathbf{t},p)$		
		D	N	I
$x_k(\mathbf{t},p)$	D	0.98	0.81	0.12
	St	0.75	0.68	0.95
	I	0.07	0.62	0.90
$z_k(\mathbf{t},p-1)$	D	0.14	0.85	0.97
	St	0.83	0.70	0.65
	I	0.91	0.63	0.18

Preprints (www.preprints.org) | NOT PEER-REVIEWED | Posted: 5 November 2018 doi:10.20944/preprints201811.0092.v1

Peer-reviewed version available at Data 2018, 3, 57; doi:10.3390/data3040057

Table A5. Primary fuzzy relations "demand – ad break-factor" after tuning

IF		THEN $a_k(\mathbf{t}, p)$		
		D	St	I
$x_1(\mathbf{t}, p)$	D	0.65	0.52	0.41
	St	0.26	0.82	0.76
	I	0.19	0.75	0.93
$x_2(\mathbf{t}, p)$	D	0.88	0.24	0.10
	St	0.43	0.59	0.25
	I	0.16	0.71	0.90
$x_3(\mathbf{t}, p)$	D	0.90	0.32	0.09
	St	0.27	0.81	0.67
	I	0.11	0.60	0.99

Table A6. Primary fuzzy relations "supply with the ad break-factor – restored genre ratings" after tuning

IF		THEN $v_k(\mathbf{t}, p)$		
		D	St	I
$z_k(y_k(\mathbf{t}, p))$	D	1.0	0.12	0
	St	0.56	0.80	0.58
	I	0.42	0.78	0.95
$a_k(\mathbf{t}, p)$	D	0.93	0.08	0
	St	0.50	0.67	0.33
	I	0.39	0.70	0.81

Table A7. Primary fuzzy relations "restored genre ratings – rating of the channel" after tuning

IF		THEN $u(\mathbf{t}, p)$		
		D	St	I
$v_1(\mathbf{t}, p)$	D	0.96	0.20	0
	St	0.45	0.84	0.57
	I	0	0.63	0.90
$v_2(\mathbf{t}, p)$	D	0.75	0.26	0
	St	0.34	0.87	0.54
	I	0	0.59	0.83
$v_3(\mathbf{t}, p)$	D	0.69	0.30	0
	St	0.33	0.76	0.51
	I	0	0.50	0.82

 doi:10.20944/preprints201811.0092.v1

Peer-reviewed version available at Data 2018, 3, 57; doi:10.3390/data3040057

Appendix B

Results of the Composite Fuzzy Model Tuning

Table B1. Solutions of fuzzy relational equations for the TV rating

Genre	**IF** μ_v^k			**THEN** $\mu_u(U_j)$
	D	St	I	
k=1	0.96–1	0–0.21	0–0.21	shD, (0.97, 0.40, 0.21)
k=2	0.75–1			
k=3	0.30–1			
k=1	0.72	0.25	0.25	mD, (0.72, 0.56, 0.25)
k=2	0.25–0.72			
k=3	0.30–1			
k=1, 2	0–0.45	0.30–0.80	0.27	wD, (0.43, 0.80, 0.27)
k=3		0.51–1		
k=1	0.45	0.84–1	0-0.51	St, (0.30, 1, 0.39)
k=2		0.30–0.84		
k=3		0.51–1		
k=1	0.34	0.76	0-0.51	wI, (0.21, 0.76, 0.54)
k=2		0.30–0.76	0-0.51	
k=3		0.76–1	0.57	
k=1	0.34	0–0.63	0.74	mI, (0.17, 0.50, 0.74)
k=2, 3			0.34–0.74	
k=1	0–0.32	0–0.32	0.90-1	shI, (0.14, 0.32, 0.91)
k=2, 3			0.82–1	

Peer-reviewed version available at *Data* **2018**, *3*, 57; doi:10.3390/data3040057

Table B2. Solutions of fuzzy relational equations for the restored genre ratings

IF						THEN
μ_Z^k			μ_a^k			$\mu_v^k(V_{kj})$
D	St	I	D	St	I	
0.93–1	0.21	0–0.21	0.93–1	0.21	0–0.21	shD, (0.96, 0.21, 0.21)
0.72 0.72–1	0.25 0–0.25	0–0.25 0.25	0.72–1 0.72	0.25 0–0.25	0–0.25 0.25	mD, (0.72, 0.25, 0.25)
0.45–1	0.80–1 0–0.80	0.27–1 0.78–1	0–0.50	0.67–1	0–0.33	wD, (0.45, 0.80, 0.27)
0.56 0–0.56 0.45	0.80–1 0.80–1 0–0.80	0–0.58 0.58 0.78–1	0–0.50 0–0.50 0–1	0.67–1 0.50–1 0.67–1	0.58–1 0.70–1 0.51	St, (0.45, 1, 0.51)
0–1 0–0.42	0.76 0–0.42	0–0.58 0.76	0–0.39 0–1	0–0.39 0.67–1	0.70–1 0.57	wI, (0.34, 0.76, 0.57)
0–0.42 0–1	0–0.42 0–0.63	0.74–1 0.74	0–1 0–0.39	0.67 0–0.39	0.74 0.74–1	mI, (0.34, 0.63, 0.74)
0–0.32	0–0.32	0.81–1	0–0.39	0–0.39	0.81–1	shI, (0.32, 0.32, 0.82)

Table B3. Solutions of fuzzy relational equations for the ad break-factor

Genre	**IF** μ_x^k			**THEN** $\mu_a^k(A_{kj})$
	D	St	I	
k=1	0.65–1	0–0.21	0–0.21	shD, (0.93, 0.21, 0.21)
k=2	0.88–1	0–0.24	0–0.24	
k=3	0.90–1	0.21	0–0.21	
k=1	0.65–0.72	0.25	0–0.25	mD, (0.72, 0.25, 0.25)
k=2, 3	0.72			
k=1	0.50–0.67	0–0.41	0–0.33	wD, (0.50, 0.67, 0.33)
k=2	0.50	0.59–0.67	0.33	
k=3	0.50	0.67	0–0.33	
k=1	0.50	0.82–1	0–0.41	St, (0.50, 1, 0.51)
k=2		0.67–1	0.51	
k=3		0.81–1	0–0.51	
k=1	0.39	0.57–0.67	0–0.57	wI, (0.39, 0.67, 0.57)
k=2	0–0.43	0.59–0.67	0.57	
k=3	0.39	0.67	0–0.67	
k=1	0.39	0–0.74	0.74	mI, (0.39, 0.59, 0.74)
k=2	0–0.43	0.59		
k=3	0.39	0–0.60		
k=1, 2	0–0.39	0.39	0.81–1	shI, (0.39, 0.39, 0.81)
k=3	0–0.27			

Table B4. Solutions of fuzzy relational equations for the control action

IF						THEN
μ_x^k			μ_z^k			$\mu_y^k(Y_{kj})$
D	St	I	D	St	I	
0.91–1	0–0.12	0–0.12	0–0.14	0–0.14	0.91–1	shD, (0.96, 0.17, 0.11)
0.73–1	0.16	0–0.16	0.38	0–0.38	0.73–1	mD, (0.73, 0.38, 0.16)
0.73–1	0.38	0.16	0.16	0.73–1	0–0.38	
0–0.38	0.73–1	0.38	0–0.16	0.16	0.73–1	
0.62–1	0.20	0–0.20	0.62–1	0.43	0–0.43	wD, (0.43, 0.62, 0.20)
0.43	0.62–1	0–0.20	0.20	0.62–1	0–0.43	
0–0.43	0.43	0.62–1	0–0.20	0.20	0.62–1	
0.81–1	0.27	0–0.27	0.81–1	0.30	0–0.30	N, (0.30, 0.96, 0.27)
0–0.30	0.81–1	0–0.27	0–0.27	0.81–1	0–0.30	
0–0.30	0.30	0.81–1	0–0.27	0.27	0.81–1	
0.74–1	0.45	0–0.45	0.74–1	0.21	0–0.21	wI, (0.21, 0.74, 0.45)
0–0.21	0.68–1	0.45	0–0.45	0.68–1	0.21	
0–0.21	0.21	0.68–1	0–0.45	0.45	0.68–1	
0.16	0.77–1	0–0.40	0.77–1	0.40	0–0.16	mI, (0.16, 0.40, 0.77)
0–0.16	0.40	0.65–1	0–0.40	0.65–1	0.16	
0–0.16	0.16	0.77–1	0.77–1	0–0.40	0.40	
0–0.14	0–0.21	0.90–1	0.90–1	0–0.21	0.14	shI, (0.11, 0.21, 0.94)

Table B5. Solutions of fuzzy relational equations for the viewers' demand

Genre	IF					THEN
	μ_t^1			μ_t^2		$\mu_x^k(X_{kj})$
	M	A	Ev	Wd	We	
k=1	0–0.15	0.79–1	0–0.15	0.56–1	0–1	shD, (0.91, 0.16, 0.12)
k=2	0.61–1	0–0.17	0–0.17	0.61–1	0–1	
k=3	0–0.15	0.59–1	0–0.15	0.81–1	0–0.59	
k=1	0–0.38	0.62–1	0–0.29	0.62–1	0.56–1	mD, (0.62, 0.38, 0.20)
k=2	0.62	0–0.50	0–0.20	0.61–1	0.61–1	
k=3	0–0.38	0.62	0–0.20	0.62–1	0–1	
k=1	0.80–1	0–0.43	0.80–1	0.73–1 0–0.73	0–0.73 0.73–1	wD, (0.43, 0.73, 0.38)
k=2	0.43	0.73–1	0–0.14			
k=3	0.65	0–0.41	0–0.41			
k=1	0.75–1	0–0.30	0.81–1	0.81–1 0–0.70	0–0.70 0.70–1	St, (0.30, 0.81, 0.27)
k=2	0.30	0.75–1	0–0.27	0.81–1 0–0.81	0–0.81 0.81	
k=3	0.65–1	0.81–1	0–0.27		0–0.81 0.81–1	
k=1	0.68	0–0.54	0–0.51	0.68–1 0–0.68	0–0.68 0.68–1	wI, (0.16, 0.68, 0.45)
k=2	0–0.22	0.68	0–0.51			
k=3	0.45	0.68	0–0.45			
k=1	0–0.65	0–0.40	0–0.65	0.65–1	0–1	mI, (0.21, 0.40, 0.65)
k=2	0–0.22	0–0.65	0.65–1	0.65	0–0.65	
k=3	0–0.21	0–0.52	0.65–1	0–0.65	0.65–1	
k=1	0–0.18	0.18	0.80–0.90	0.80–1	0–0.59	shI, (0.14, 0.21, 0.80)
k=2	0–0.22	0–0.51	0.80–1	0–0.80	0.80–1	
k=3	0–0.17	0.21	0.72–1	0–1	0.72–1	

Peer-reviewed version available at *Data* **2018**, *3*, 57; doi:10.3390/data3040057

References

1. Žilic Fišer, S. *Successful Television Management: the Hybrid Approach*. Peter Lang GmbH: Int. Verlag der Wissenschaften, Germany, 2015; 169 p., ISBN: 978-3-653-96696-1.
2. Schuurman, D.; Marez, L.D.; Veevaete, P.; Evens, T. Content and context for mobile television: integrating trial, expert and user findings. *Telematics and Informatics* **2009**, *Volume* 26 (3), pp. 293–305, DOI: 10.1016/j.tele.2008.11.004.
3. Véras, D.; Prota, T.; Bispo, A.; Prudêncio, R.; Ferraz, C. A literature review of recommender systems in the television domain. *Expert Syst. Appl*. **2015**, *Volume* 42 (22), pp. 9046–9076, DOI: 10.1016/j.eswa.2015.06.052.
4. Oh, J.; Kim, S.; Kim, J.; Yu, H. When to recommend: a new issue on TV show recommendation. *Information Sciences* **2014**, *Volume* 280, pp. 261–274, DOI: 10.1016/j.ins.2014.05.003.
5. Park, Y.; Oh, J.; Yu, H. RecTime: Real-Time recommender system for online broadcasting. *Information Sciences* **2017**, *Volume* 409–410, pp. 1-16, DOI: 10.1016/j.ins.2017.04.038.
6. Fraile, F.; Guerri, J.C. Simple models of the content duration and the popularity of television content. *Journal of Network and Computer Applications* **2014**, *Volume* 40, pp. 12–20, DOI: 10.1016/j.jnca.2013.08.010.
7. Moreno, M.; Segrera, S.; López, V.; Munoz, M.; Sánchez, Á. Web mining based framework for solving usual problems in recommender systems. A case study for movies' recommendation. *Neurocomputing* **2016**, *Volume* 176, pp. 72-80, DOI: 10.1016/j.neucom.2014.10.097.
8. Zhang, Y.; Chen, W.; Yin, Z. Collaborative filtering with social regularization for TV program recommendation, *Knowledge-Based Systems* **2013**, *Volume* 54, pp. 310–317, DOI: 10.1016/j.knosys.2013.09.018.
9. Xu, Y.; Yin, J. Collaborative recommendation with user generated content. *Eng. Appl. Artif. Intell.* **2015**, *Volume* 45, pp. 281–294, DOI: 10.1016/j.engappai.2015.07.012.
10. Wang, Z.; He, L. User identification for enhancing IP-TV recommendation. *Knowledge-Based Systems* **2016**, *Volume* 98, pp. 68–75, DOI: 10.1016/j.knosys.2016.01.018.
11. Boratto, L.; Carta, S.; Fenu, G. Investigating the role of the rating prediction task in granularity-based group recommender systems and big data scenarios. *Information Sciences* **2017**, Volume 378, pp. 424–443, DOI: 10.1016/j.ins.2016.07.060.
12. Panova, E.; Raikov, A.; Smirnova, O. Cognitive television viewer rating. *Procedia Comput. Sci.* **2015**, *Volume* 66, pp. 328–335, DOI: 10.1016/j.procs.2015.11.038.
13. Lin, J.-S.; Sung, Y.; Chen, K.-J. Social television: examining the antecedents and consequences of connected TV viewing. *Computers in Human Behaviour* **2016**, *Volume* 58, pp. 171–178, DOI: 10.1016/ j.chb.2015.12.025.
14. Danaher, P.; Dagger, T.; Smith, M. Forecasting television ratings. *International Journal of Forecasting* **2011**, *Volume* 27 (4), pp. 1215-1240, DOI: 10.1016/j.ijforecast.2010.08.002.
15. Kotkov, D.; Wang, S.; Veijalainen, J. A survey of serendipity in recommender systems. *Knowledge-Based Systems* **2016**, Volume 111, pp. 180-192, DOI: 10.1016/j.knosys.2016.08.014.
16. Belanche, D.; Flavián, C.; Pérez-Rueda, A. User adaptation to interactive advertising formats: The effect of previous exposure, habit and time urgency on ad skipping behaviors. *Telematics and Informatics* **2017**, *Volume* 34 (7), pp. 961-972, DOI: 10.1016/j.tele.2017.04.006.
17. Abrahams, A.; Coupey, E.; Zhong, E.; Barkhi. R.; Manasantivongs, P. Audience targeting by B-to-B advertisement classification: A neural network approach. *Expert Syst. Appl.* **2013**, *Volume* 40 (8), pp. 2777-2791, DOI: 10.1016/j.eswa.2012.10.068.
18. Wang, G.; Zhuo, L.; Li, J.; Ren, D.; Zhang, J. An efficient method of content-targeted online video advertising. *J. Visual Commun. Image Represent*. **2018**, *Volume* 50, pp. 40-48, DOI: 10.1016/j.jvcir.2017.11.001.
19. Rotshtein, A.; Rakytyanska, H. *Fuzzy Evidence in Identification, Forecasting and Diagnosis*. Studies in Fuzziness and Soft Computing, *Volume* 275; Springer: Heidelberg, Germany, 2012; 313 p., ISBN: 978-3-642-25785-8.
20. Rotshtein, A.; Rakityanskaya, A. Inventory control as an identification problem based on fuzzy logic. *Cybern. Syst. Anal*. **2006**, *Volume* 42 (3), pp. 411–419, DOI: 10.1007/s10559-006-0078-3.
21. Azarov, O.; Krupelnitsky, L.; Rakytyanska, H. A fuzzy model of television rating control with trend rules tuning based on monitoring results. In Proceedings of the 2018 IEEE Second International Conference on Data Stream Mining & Processing (DSMP); Lviv, Ukraine, August 21-25, 2018, pp. 369-375. ISBN: 978-1-5386-8175-6.

Peer-reviewed version available at *Data* **2018**, *3*, 57; doi:10.3390/data3040057

22. Yager, R.; Filev, D. *Essentials of Fuzzy Modeling and Control*. Willey: New York, USA, 1994; 408 p., ISBN: 978-0471017615.
23. Peeva, K.; Kyosev, Y. *Fuzzy Relational Calculus. Theory, Applications and Software*. World Scientific: New York, USA, 2004; 291 p., ISBN: 978-9812560766.
24. Rotshtein, A.; Rakytyanska, H. Expert rules refinement by solving fuzzy relational equations. In Proceedings of the VIth IEEE Conference on Human System Interaction; Sopot, Poland, June 6-8, 2013, pp. 257–264, DOI: 10.1109/HSI.2013.6577833.
25. Rotshtein, A.; Rakytyanska, H. Optimal design of rule-based systems by solving fuzzy relational equations. In *Issues and Challenges in Artificial Intelligence. Studies in Computational Intelligence*; Hippe, Z., Kulikowski, L., Mroczek, T., Wtorek, J., Eds.; Springer: Cham, Switzerland, 2014; Volume 559, pp. 167–178, ISBN: 978-3-319-06882-4.
26. Rakytyanska, H. Fuzzy classification knowledge base construction based on trend rules and inverse inference. *Eastern-European Journal of Enterprise Technologies* **2015**, *Volume* 1(3), pp. 25–32, DOI: 10.15587/1729-4061.2015.36934.
27. Rakytyanska, H. Classification rule hierarchical tuning with linguistic modification based on solving fuzzy relational equations, *Eastern-European Journal of Enterprise Technologies* **2018**, *Volume* 1(4), pp. 50–58, DOI: 10.15587/1729-4061.2018.123567.
28. Rotshtein, A.; Rakytyanska, H. Adaptive diagnostic system based on fuzzy relations. *Cybern. Syst. Anal.* **2009**, *Volume* 45(4), pp. 623–637, DOI: 10.1007/s10559-009-9130-4.
29. Rotshtein, A.; Rakytyanska, H. Fuzzy logic and the least squares method in diagnosis problem solving. In *Genetic Diagnoses*; Sarma, R., Ed.; Nova Science Publishers: New York, USA, 2011; pp. 53–97, ISBN**:** 978-1-61324-866-9.
30. TV Channel Inter: Ratings. Available online: http://inter.ua/uk/about/rating
31. TV Channel Inter: Weekly TV Program. Available online: https://inter.ua/uk/tv
32. IMDb Top Rated Movies. Available online: https://www.imdb.com
33. Ukrainian Films Catalog. Available online: https://kinoafisha.ua/ratings/
34. Azarov, O.D.; Krupelnitsky, L.V.; Steiskal, V.Y.; Bilokon', O.A. *Specialized and Measuring Equipment of Own Design and Production for TV and Radio Broadcasting,* Catalog of the Scientific and Technical Center «Analog-Digital Systems», VNTU: Vinnitsya, Ukraine, 2015. http://ot.vntu.edu.ua/katalog.