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MODELLING CONFLICT DYNAMICS IN AN ENERGY SUPPLY SYSTEM

MODELIRANJE DINAMIČNIH KONFLIKTOV V ENERGETSKEM SISTEMU

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Keywords: conflict, generic model, social interaction, stock-and flow diagram, system dynamics, fuzzy inference system

Abstract

This paper presents a model of conflict, the precise definition of which is also presented in this paper. The system dynamics paradigm is often used to model the dynamics of social interactions. The basic ideas leading to conflict models in form of difference, i.e. differential equations, and finally to an expanded model with fuzzy logic inference are presented.

Tremendous progress in this field has been made by two groups of researchers. Gottman et al., [1], modelled marital interactions and set up a model in the form of differential equations. Coleman in his group, [2], established the model of group interaction in the form of differential equations. There are many types of social interactions; conflict is merely one of them. We define conflict as a destructive, dysfunctional interaction between actors. According to this view, we developed a conflict model, arising from the model of Coleman et al., first in the form of differential equations and then in the form of a stock-and-flow diagram, according to paradigm of system dynamics. We attempted to keep the results of the model understandable for a broad range of managers and officials at different levels within the energy sector. At the end, a numerical example is given.

Povzetek

V članku je predstavljen dinamični model konflikta. Dinamiko odnosov in relacij v modelu za zvezne sisteme opišemo z uporabo diferencialnih enačb. v nadaljevanju razvoja teorije pa model

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nadgradimo še z uporabo mehke logike. Velik napredek na tem področju sta opravili dve ločeni raziskovalni skupini. Gottman, Murray in ostali, [1], so se ukvarjali z odnosi med zakoncema, kar so modelirali s sistemom diferenčnih enačb. Skupina raziskovalcev pod vodstvom Colemana, [2], pa je razvila model v obliki diferencialnih enačb. Obstaja mnogo vrst družbenih interakcij, konflikti so le ena od njih. V članku izhajamo iz definicije, ki opredeljuje konflikt kot destruktivno neuglašeno zvezo med dvema akterjema. Glede na to definicijo postavimo model konflikta v skladu s Colemanovim pristopom najprej v obliki sistema diferencialnih enačb, ki ga rešujemo s pomočjo grafičnega pristopa sistemske dinamike. Rezultate lahko uporabimo na širokem področju upravljanja sistemov. Vsi izsledki, relacije in rezultati veljajo tudi za področje upravljanja energetskega sistema. Na koncu članka je dodan numerični primer, ki ilustrira teoretično podlago modela.

1 INTRODUCTION

Different conflicts can be observed in the energy sector at any level of society, from individual, organizational, intra-state, to the international level. There are conflicts about the use of energy resources, building power plants and investment priorities. There are opposing interests between legislators, producers and consumers that lead to conflicts. Ecologists oppose nearly every interference in the environment. Local communities often oppose transmission lines, as the storage and transportation of nuclear waste etc. Many international conflict occur around the crude oil, gas resources and pipelines.

Some conflicts will be settled without any outside intervention; others will escalate to a certain level and remain stabilised at that level, and there are also conflicts that will oscillate.

Do we really understand the mechanisms driving conflict dynamic? What do all these conflicts have in common?

We see conflict as a specific malignant kind of social interaction, usually between two parties (actors). Conflict is something that should be settled and reconciled. Not all scholars share this opinion; some see conflict as driving force of progress. If we would like to affect full reconciliation, it is useful to understand conflict dynamics. This paper takes a closer look into the internal workings of conflict dynamics.

2 MODELLING CONFLICT DYNAMICS – OVERVIEW

Studies of conflict dynamics are mostly based on the theoretical works of Deutsch, [3, 4], Richardson, [5], Pruitt [6-9], and Coleman [10].

Coleman characterized an intractable conflict as 'one that is recalcitrant, intense, deadlocked, and extremely difficult to resolve', [10]. Deutsch explained this with his so-called crude law of social relations: 'The characteristic processes and effects elicited by a given type of social relationship (cooperative or competitive) also tend to elicit that type of social relationship', [11]. The concepts of conflict dynamics in the context of cooperation and competition as developed by Deutsch, [10], drive the conflict into one of the stable states, i.e. the attractors, [2, 12]. Many conflicts are settled before they escalate. It must be noted that not every divergence can be characterized as conflict. However, if a conflict develops in a destructive direction and is not settled on time it will most probably escalate accompanied by series of incremental

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transformations, [9]. The narrow, but consistent, and stable structure of emotions, perceptions, beliefs, feelings, values, thinking, behaviours and communication arise. Once structural changes are strengthened, they become difficult to eliminate, and conflict become intractable. As we will see later, a conflict can reach a certain stable state, known as the 'attractor', and conflict dynamics maintain this stable state. Nothing can grow endlessly, and the psychological states of actors will reach a stable or unstable equilibrium. The conflict spiral will go forwarded but conflict will no longer escalate, [9].

Two groups of researchers, Gottman-Murray et al. (Gottman, Murray, Tayson, Swanson and Swanson) and Coleman et al. (Coleman, Vallacher, Nowak, Liebovitch, Bui-Wrzosinska), have significantly contributes to understanding conflict dynamics.

3 THE MODEL OF GOTTMAN ET AL.

Gottman et al. developed a formal mathematical model of marital conflicts as the theory [1, 13]. The emotional state (behaviour) of wife to her husband is denoted W_t, and emotional state (behaviour) of husband to his wife is denoted H_t ($t = 1,2,3,....$). W_t and H_t can be positive or negative. The rates of change of emotional states are determined by two components: the influenced component and the uninfluenced component. The uninfluenced component reflects the behaviour of one partner, when she or he is not influenced by other partner. Gottman et al. formulated the influence of the husband behaviour on his wife, respectively the wife's behaviour on her husband with influence functions denoted as $I_{HW}(H_t)$, and $I_{WH}(W_t)$. A complete model with influence functions is presented by the difference equations

$$W_{t+1} = I_{HW}(H_t) + r_1 W_t + a \tag{3.1}$$

$$H_{t+1} = I_{WH}(W_{t+1}) + r_2 H_t + b \tag{3.2}$$

$$t = 0, 1, 2, ...$$

where the constants *a* or *b* reflects the essence of nature of each person, and the constants r_1 or r_2 determine how quickly the person will return to its set point when it is uninfluenced. The constants r_1 and r_2 are known as the inertia to change. Only values of $|r_i| < 1$, *i =1, 2* are meaningful, because only in this case will the system move towards its steady state.

The model was improved and expanded Gottman et al., [1].

4 THE MODEL OF COLEMAN ET AL.

Coleman, Vallacher, Nowak, Liebovitch, Bui-Wrzosinska developed mathematical model of conflict between two actors in the form of two nonlinear ordinary differential equations (Liebovitch, et al., 2008).

$$\frac{dx}{dt} = m_1 x + b_1 + c_1 \cdot tgh\, y \tag{4.1}$$

$$\frac{dy}{dt}=m_2y+b_2+c_2\cdot tgh\,x \qquad (4.2)$$

where $x(t)$ and $y(t)$, $t\in[0,T]$,$T<\infty$ represent the emotional state of each actor, and can be positive or negative. Both of these influence functions are presented as hyperbolic tangent functions. The terms m_1x and m_2y represent the inertia to change and constants b_1 and b_2 drive the uninfluenced changes. Colman et al. analysed three different interactions between actors: positive feedback between both groups ($c_1>0$, $c_2>0$), negative feedback between groups ($c_1<0$, $c_2<0$) and positive feedback from one group and negative feedback from the other group ($c_1>0$, $c_2<0$), [14].

5 MODEL OF ISOLATED CONFLICT

Formal modelling of conflict requires a rigorous definition of this phenomenon. There are many definitions that emphasize different aspects and/or types of conflict. According to our understanding, we developed the following working definition of conflict: conflict is always a destructive, dysfunctional social interaction between actors that is characterised by a perception of incompatibility of goals, interests, values, beliefs, preferences etc., which is mirrored in the hostile emotional states of the actors. The gravity of conflict can be measured as the levels of emotional states of actors. We stick to the traditional view of conflict, which considers the conflict as something negative, which is connected with quarrelling, psychopathology, social unrest, etc., In all cases, conflict is disturbance, which has to be reconciled or abolished, [15]. We will limited our discussion (and modelling) to conflicts between two actors, i.e. to dyadic conflicts.

5.1 The model

Our proposed model of isolated conflict arises out of the Coleman model of Equations (4.1), (4.2). We have modified this according to our definition of conflict. The values of both of the variables presenting (hostile) emotional states of both of the actors can only be positive or zero. Conflict exists or it does not exist; it might be stable or it might escalate, de-escalate or oscillate. This means the $x(t)\geq 0$ and $y(t)\geq 0$ for all $t\in[0,T]$. One of the reasons for this is our intention to include interactions between conflict and its environment later on. Reactions of the environment to conflict are entirely different from reactions to cooperation. The model of isolated conflict should be easy to widen with fuzzy logic inference. In this context, the differential equations modelling conflict have meaning only in the first quadrant. The influence functions remain S-shaped. We shifted the hyperbolic tangent functions into the first quadrant, and modified them. We used the following form of influence functions:

$$f_1(y)=\frac{tgh\left(\frac{y}{g}-h\right)+1}{2} \qquad (5.1)$$

$$f_2(x)=\frac{tgh\left(\frac{x}{g}-h\right)+1}{2} \qquad (5.2)$$

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where parameter g accommodates the slope of both of the functions, and extends them, parameter h determines the shit of hyperbolic tangent to right. The value of h is chosen so that the values of functions (5.1) and (5.2) for $x=0$ and $y=0$, respectively, are close enough to zero. The proposed model is given by two differential equations:

$$\frac{dx}{dt}=m_1x+b_1+c_1\frac{tgh\left(\frac{y}{g}-h\right)+1}{2} \tag{5.3}$$

$$\frac{dy}{dt}=m_2y+b_2+c_2\frac{tgh\left(\frac{x}{g}-h\right)+1}{2} \tag{5.4}$$

Parameters m_1 and m_2 ($m_1<0, m_2<0$) reflect the resistance against the conflict. In our model, this resistance should grow in proportion with emotional state; it is the result of many factors, such as costs of conflict, limitation of resources, and also ethical norms and values. For international or ethnical conflicts, public opinion play an important role. The terms $m_1.x$ and m_2y are limiting to the growth of the conflict. The constants b_1, b_2, m_1 and m_2 determine the uninfluenced set points, and the rates of change in the emotional states without outer influences. Constants b_1 and b_2 can be positive or negative. A positive value means that without the influence of another actor, the emotional level will become increasing hostile against the other actor until a set point is reached. The constants present the basic attitude of one actor against the other actor. This also means that conflict is unavoidable. Negative values of constants b_1 and b_2 will drive the emotional level in opposite direction, towards zero.
Our major concern is the behaviour of model. What drives the conflict? How do different values of parameters influence its behaviour? What kind of behaviour can we expect? Where are the critical points, and are they stable?

There are few methods to answer such kinds of questions. We can use the phase plane (*x*-*y*), to present the whole family of solutions. This is a very useful qualitative method for analysing the system of a differential equations, [16].

Another possibility to solve and analyse these differential equations is to use Laplace or z-transformation, and map in to complex plane, [17, 18]. In this case, we have to use piecewise linear function on a finite interval $a \le t \le b$ where the function is defined, instead of the tangent function. This will change the conditions of conflict, so we decided to take another approach.

When the models are more sophisticated, when they include fuzzy variables and fuzzy logic inference, then they cannot be formulated as a system of differential equation, and we need other tools to model and analyse conflicts. The system dynamics paradigm, and stock-and-flow modelling is a convenient alternative.

5.1.1 Stock-and-Flow model of conflict

We translate the system of differential equations (5.3) and (5.4) into a so-called stock-and-flow model. The model can be simulated on the computer, and its behaviour can be observed in detail. We used the stock-and flow-modelling methodology, based on system dynamics paradigm as defined by Forester, [19, 20], and Bossel, [21], and further developed at the Massachusetts Institute of Technology. This modelling methodology is widely used in different

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fields, such as mathematical biology, management, social science, physics, chemistry, and environmental sciences. At present, there are a few software packages that implement system dynamics modelling, the most popular of which are Vensim, STELLA and iThink. We used the Vensim PLE. The model is shown in Figure 1.

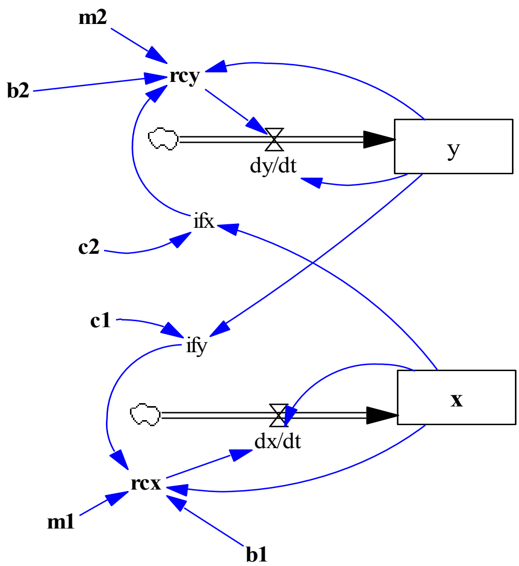

Figure 1: *Stock-and-Flow model*

6 SIMULATION RESULTS

We can run the model with different values of parameters, and different initial value $x(0), y(0)$. We will see four different types of behaviour:

1. The model has one stable point, which is high. The emotional levels $x(t)$ and $y(t)$ go asymptotically to the stable point, independently of the initial values $x(0), y(0)$ (See Figure 2)
2. The model has two stable points, one high and one low. The emotional levels $x(t)$ and $y(t)$ go asymptotically to the higher or to the lower stable point, depends on the initial values $x(0), y(0)$ (Figures 3 and 4)
3. If the lower stable state is negative (in the third quadrant), and initial values $x(0), y(0)$ are below a threshold value, $x(t)$ and $y(t)$ will de-escalate toward the lower stable, point which is negative. When they achieve value zero at a time t_{zero}, the conflict is over, and $x(t)=0, y(t)=0$ for $t \ge t_{zero}$ (Figure 5).
4. The model has one stable point, which is low. The emotional levels $x(t)$ and $y(t)$ go asymptotically to the stable state, independently of the initial values $x(0), y(0)$ (Figure 6)

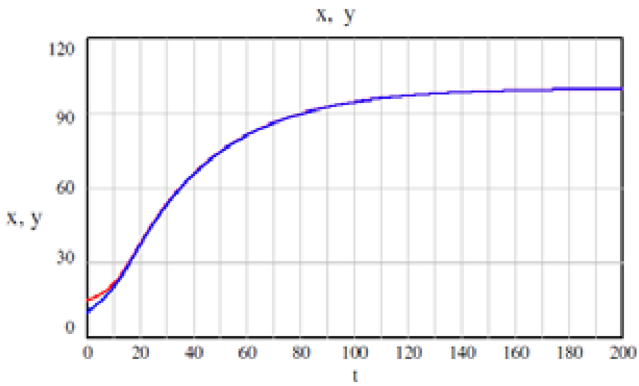

Figure 2: *Emotional levels. Parameters:* m_1=m_2=-0.03; c_1=c_2=2.5; b_1=b_2=0.5.
Initial values x(0)=10, y(0)=15

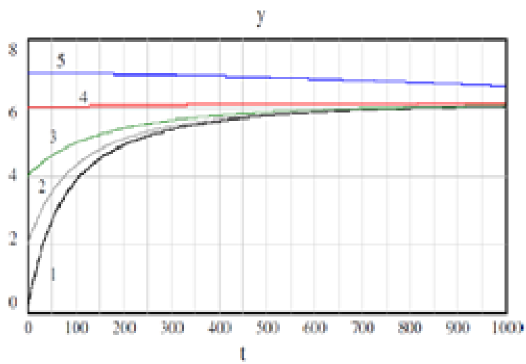

Figure 3: *Emotional level y(t). Parameters:* m_1=m_2=-0.03; c_1=c_2=2.5; b_1=b_2=0.037.
Initial values: x(0)=y(0)= 1:(0.1, 0.1), 2:(2, 2), 3:(4, 4), 4:(6, 6), 5:(7, 7)

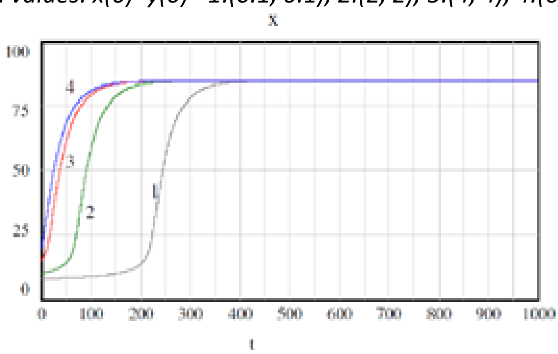

Figure 4: *Emotional level y(t). Parameters:* m_1=m_2=-0.03; c_1=c_2=2.5; b_1=b_2=0.037.
Initial values: x(0)=y(0)=1:(8, 8), 2:(10, 190), 3:(15, 15), 4:(20, 20)

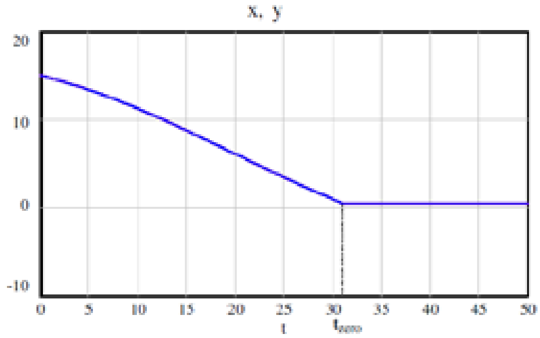

Figure 5: *Emotional levels. Parameters:* $m_1=m_2=-0.03$*;* $c_1=c_2=2.5$*;* $b_1=b_2=-0.5$*.*
Initial values: x(0), y(0)= 15

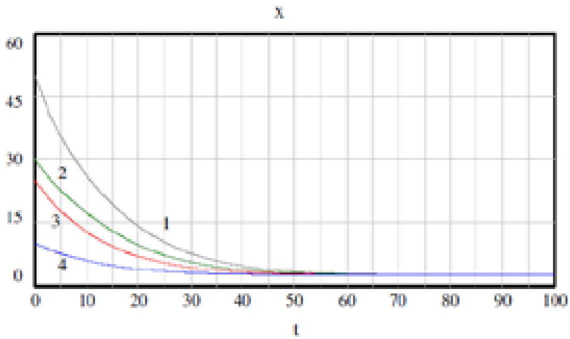

Figure 6*: Emotional levels x(t). Parameters:* $m_1=m_2=-0.09$*;* $c_1=c_2=0.75$*;* $b_1=b_2=0.2$*.*
Initial values:(x(0), y(0)= 1: (50, 50), 2: (30, 40), 3: (25, 20), 4: (10, 14)

7 EXPANDED GENERIC MODEL OF CONFLICT

When conflict is observed under the axioms of systems theory, then this is an open system. This means that it interacts with its own environment. Now many questions arise:

1. What (or better who) is the conflict environment? We will use the term 'stakeholders', which could refer to one or many.
2. How do stakeholders react to the conflict? Are they interested in resolving or at least diminishing the conflict? Or do they desire that the conflict should remain at the certain level, or even escalate?
3. How do they intervene in the conflict?
4. What is the logic behind the intervention?

The answer to all these questions depends on where the conflict arises, at which level of society, and the interests and possibilities of stakeholders.

Our aim is a generic model of conflict. So we have limited this research to organisational conflicts with only one stakeholder: management with the interest to solve or diminish the conflict.

In terms of the model we have to mimic people's reasoning. Fuzzy logic is an appropriate methodology for this. We decided to use a fuzzy rule-based inference, which we modelled in

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accordance with the systems dynamics paradigm. Our modelling approach has been inspired by Lui et al., [22,23]. The generic conflict model expanded with the fuzzy logic inference is presented in Figure 7.

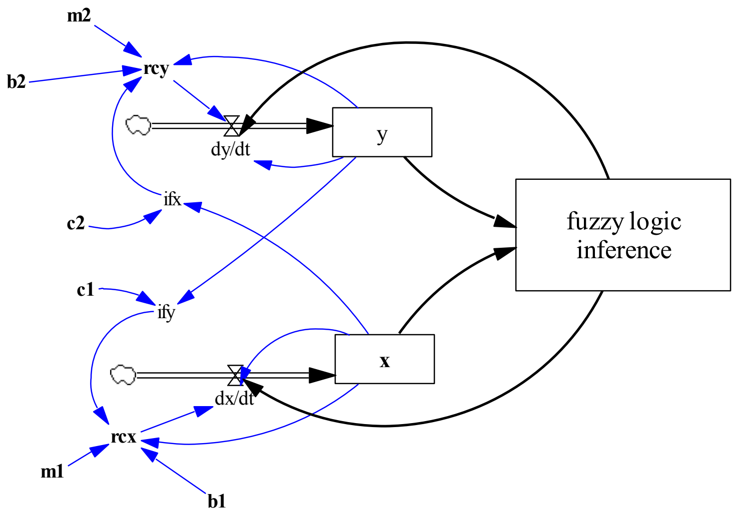

Figure 7: *Expanded generic model of conflict (stock-and-flow model)*

The detailed description of the fuzzy logic inference model, [24], is beyond the scope of this paper.

8 CONCLUSIONS

The aim of the generic model of conflict in the form of differential equations or stock-and-flow models (or even more broadly, in the form of an executable computer program) is to explain the mechanism (structure) that drives the dynamics of conflict. Conflict behaviour depends on the structural parameters *b*, *m*, and *c*, their values, and mutual relations/structure of conflict. The values of these parameters are intrinsic characteristics of the actors involved. Where the conflict will go depends on the relations between the vales of parameters, and also on the form of the initial emotional levels. As mentioned above, if the model cannot be expressed as a system of differential equations, the stock-and-flow simulation remains a convenient tool to cope with conflict dynamics. We have presented the model of conflict and we emphasised that the conflicts happen in a certain environment that both influences and is influenced by conflict. Stock-and-flow models are easy to understand, and they do not require a deeper knowledge of calculus. Such models could serve as a useful learning tool for anyone who is dealing with managing conflicts.

References

[1] **Gottman, J. M., Murray, J. D., Swanson, C. C., Tayson, R., Swanson, K. R.** (2005). *The Mathematics of Marriage.* Cambridge: MIT Press. Journal of Family Psychology, 13(1), pp. 3–19.

[2] **Coleman, P. T., Vallacher, R., Nowak, A., & Bui-Wrzosinska, L.** (2006). *Intractable Conflict as an Attractor: Presenting a Dynamical Model of Conflict, Escalation, and Intractability.* American Behavioral Scientist.

[3] **Deutsch, M.** (1973). *The resolution of Conflict: and Destructive Processes*. New Haven: Yale University Press.

[4] **Deutsch, M.** (2006). *Corporation and Competition.* In *The Handbook of Conflict: Theory and Practice*. Deutsch M., Colman P.T. & Marcus E. C. as editors. John Wiley Press, pp.23–42.

[5] **Richardson, L. F.** (1967). *Arms and Insecurity.* Chicago: Quadrangle.

[6] **Pruitt D. G.** (1969). *Stability and sudden change in interpersonal and international affairs*. Journal of Conflict Resolution 13, pp.1838.

[7] **Pruitt D. G**. (2006). *A graphical Interpretation of Escalation and De-escalation*. Presented at Dynamics and Complexity of Intractable Conflicts. Kamimierz, Poland, pp. 19–22.

[8] **Rubin, J. Z., Pruit D. G., & Kim S. H.** (1994). *Social Conflict Escalation, Stalemate and settlemen*t. McGraw Hill.

[9] **Pruitt D. G., Kim** (2004). Social *Conflict Escalation, Stalemate, and Settlemen*t. McGraw Hill.

[10] **Coleman, P. T.** (2000). *Fostering ripeness in seemingly intractable conflict: An experimental study.* International Journal of Conflict Management, 11(4), pp. 300–317.

[11] **Deutsch, M.** (2005). *Cooperation and Conflict: A personal perspective on the history of the social psychological study of Conflict resolution.* In *The Essentials of Team working: International Perspectives,* Edited by West, M. A., and all, John Wiley & Sons, Ltd., *pp. 1–36.*

[12] **Vallacher, R.R., & Nowak, A.** (2005). *Dynamical social psychology: finding order in the flow of human experiences.* In A.W. Kruglanski & E.T. Higgins (Eds.), Social Psychology: Handbook of Basic Principles. New York: Guilford Publications.

[13] **Gottman, J., Swanson, C., & Murray** (1999). *The Mathematics of Marital,* Conflict: Dynamic Mathematical Nonlinear Modeling of Newlywed Marital Interaction.

[14] **Liebovitch, L. S., Naudot, V., Vallacher, R. A. Nowak, A., Bui-Wrzosinska, L., Coleman, P.T.** (2008). *Dynamics of two-actor cooperation-competition conflict models*. Physica A doi:10.1016/j.physa.2008.07.020.

[15] **Robbins, S. P.** (2005). *Organizational Behavior*. New Jersey Pearson Education Inc.

[16] **Kreyszig E (2011)**. *Advanced Engineering Mathematics*. John Wiley & Sons. Inc. 10^{TH} edition.

[17] **Usenik, J.** (2009). *Mathematical model of the power supply system control*. Journal of Energy Technology, Aug. 2009, vol. 2, iss. 3, pp. 29–46.

[18] **Usenik, J., Repnik, M.** (2012). *System control in conditions of discrete stochastic input process*, Journal of energy technology, Feb. 2012, vol. 5, iss. 1, pp.37–53.

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[19] **Forrester J. W.** (1968). *Principle of Systems* (1980); 2nd. Preliminary Edition; MIT Press.

[20] **Sterman J. D.** (2000). *Business Dynamics Systems Thinking and Modeling for a Complex World*; Irwin McGraw-Hill.

[21] **Bossel, H.** (2004). *Systeme Dynamik Simulation Modellbildung, Analyse und Simulation komplexer Systeme*. Books on Demand GmbH, Norderstedt.

[22] **Liu, S.** (2007). *Three Essays on Travel Demand Management Strategies for Traffic Congestion Mitigation*. Dissertation Submitted to the Faculty of Virginia Polytechnic Institute and State University in partial fulfillment of the requirement for the degree of Doctor of Philosophy in Industrial & Systems Engineering.

[23] **Liu, S, Triantis, K. P., & Sarangi, S.,** (2011). *Representing Qualitative Variables and Their Interactions With Fuzzy Logic in System Dynamics Modeling. Systems Research and Behavioral Science Syst. Res.* Published online in Wiley Online Library Research Paper, pp.245–263.

[24] **Usenik, J., Turnšek, T.** (2013). *Modeling Conflict Dynamics With Fuzzy Logic Inference,* Journal of US-China Public Administration 10 (5).