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CONTROL IN A HIERARCHICAL ACTIVE SYSTEM ON THE BASIS OF ENTROPY PARADIGM OF SUBJECTIVE ANALYSIS

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Abstract

The theory of conflicts, as conflicts of preferences distributions, is developed on the basis of this model. A classification of conflicts that reflects, to a significant degree, the existing knowledge in this field is proposed. A conflict transformation from one phase into another is connected with overcoming certain entropy thresholds is considered to be. The dynamics of conflicts, intrapersonal and interpersonal conflicts.

The authors discuss a hierarchical system control tasks, diagnostic and preventive measures of a conflict. A control at the stage of the conflict being such a cold conflict. Productive conflicts having often form of a competition, opposition and they stop the destructive conflicts. A subjective analysis provides a method for a formalization of a cold conflict when "muses are silent" go to the hot conflict, when the "cannons thunder", as well as models of the dynamics of mental processes within a paradigm of entropy.

Keywords: *active system, preferences distribution, interpersonal conflict, intrapersonal conflict, dynamics of conflicts.*

INTRODUCTION

The presented paper is a continuation of the first paper “Entropy paradigm in the theory of hierarchical active systems. Elements of conflict theory” [22].

Materials related to a control of conflicts in a transient two-level system are represented in this paper.

Tasks of control in a hierarchical system

In this paper are described the principles and algorithms of control in an active system and represented some results of numerical modelling.

Tasks of control in a hierarchical system − diagnostics and preventive measures of conflicts; a control is supposed to occur at the stage when a *cold conflicts* is about to happen; support and governing *productive conflicts*, often having a form of a competition, an opposition and a suppression of *destructive* or *counterproductive conflicts* having in its basement antagonisms.

Subjective analysis offers a method of formalization for a *cold conflict*, when "muses are silent", transition to the stage of a *hot conflict*, when "cannons thunder", as well as models of psychic processes dynamics in the framework of an entropy paradigm.

A problem of control of a hierarchical system is solved in two stages:

- the control of the process of decision making – choosing an alternative at the set of S_a, hence a goal; and
- the control of the process of a goal achievement.

In a two-level system, it is natural to deem that the right of choice, i.e. decision making, pertains to the subject of the top level, that is the subject *A* – the first pilot, a captain of the aircraft crew. However, this happens while taking into account the presence of preferences, resources of *B*, both active and passive.

Figuratively speaking, it is possible to say, that *external control* "realizes a variational principle", without our awareness, "founded, embedded" in our consciousness, at the moment of making a choice. But we accept that there can be an external manager, a *governor* – the 3rd subject, who believes in the justice of the postulate of the subjective optimality, i.e. preferences are formed in the correspondence with a variational principle. Then, the *external control* is realized accordingly to the scheme (Fig. 1):

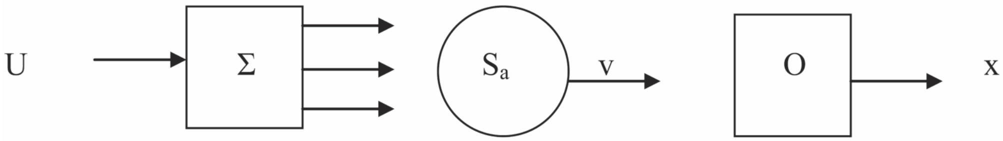

Fig. 1. Scheme of external control, subject and object [K. Szafran, 2014]

The control of the object O is realized by non-direct means. The *external governor* manages the subject Σ thinking that the subject will be reacting in accordance with the variational principle (postulate of subjective optimality).

At the second stage – a realization of the choice and the chosen goal achievement – the subject Σ is the manager. They solve the main problem of control by using traditional methods, determined by objective factors and objective estimations.

The first problem – a control of the choice is solved in the framework of subjective analysis; the second one – achieved by the means of traditional theory of control methods.

It is assumed that, within the system, there are certain available resources, which are *under control* of subjects *A* and *B*; i.e. R_A^{av} and R_B^{av}. In the process of the problem solving the resources are exhausted and also they are being over-distributed amongst the levels of *A* and *B*.

In a more general view, we can talk about individual utilities and mutual utilities: [3, 5] $U(i \to j)$– usefulness of subject *i* for subject *j*.

There are the following forms of connectivity in hierarchical systems:

- a common character of problems (non-empty intersections of sets of alternatives) $S_a(A) \cap S_a(B) \neq \varnothing$;
- a common character of resources (consolidated resources for corporative problems);
- the presence of mutual utilities;
- a common character of interests, desires, preferences; desires are considered as extensive characteristics, preferences – intensive ones;
- a common character of ethics imagination, acknowledged ethics imperatives.

Finally, we can talk about informational subjective connectivity between the subjects inside a hierarchical system.

Properties of the individuality are usually considered in the theory of collective decisions [17]. Models of preferences aggregation and recursive models play an important role in it. It is possible to describe the difference between horizontal and vertical conflicts with their help. In the first case, the model is a symmetrical one, in the second *vertical* – asymmetrical. A conflict, like other important categories: freedom, social justice etc., has a dynamical character and is to be considered as a process.

An accepted model for such processes is a recursive model. An application of recursion allows solving an improvement of significant nonlinearities, arising at aggregation of preferences, besides, being in relation with the real character of the considered phenomena.

According to the *principle of an individual bearer*, let us compile the functional of $\Phi_{\pi A}$ and $\Phi_{\pi B}$ corresponding to the two-point distributions of $\pi_A(\sigma_{Ai}, \sigma_{Bk})$ and $\pi_B(\sigma_{Bk}, \sigma_{Ai})$ for each subject (in the given case for subjects A and B). Let us choose the functional of $\Phi_{\pi A}$ in the following view:

$$\Phi_{\pi A}(A,B) = -\sum_{i=1}^{N_1}\sum_{k=1}^{N_2}\pi_A(\sigma_{Ai},\sigma_{Bk})\ln\pi_A(\sigma_{Ai},\sigma_{Bk}) + \\ +\sum_{i=1}^{N_1}\sum_{k=1}^{N_2}\pi_A(\sigma_{Ai},\sigma_{Bk})\cdot\left[\beta F_A\left(A\middle|B,\sigma_{Ai},\sigma_{Bk}\right)+\alpha\ln F_A\left(A\middle|B,\sigma_{Ai},\sigma_{Bk}\right)\right]+ \\ +\gamma\sum_{i=1}^{N_1}\sum_{k=1}^{N_2}\gamma_k\cdot\pi_A(\sigma_{Ai},\sigma_{Bk}). \tag{1}$$

Accepting

$$\pi_A(\sigma_{Ai},\sigma_{Bk}) = \pi_B(\sigma_{Bk})\cdot\pi_A\left(\sigma_{Ai}\middle|\sigma_{Bk}\right),\ N_1 = N_2 = N, \tag{2}$$

we will get:

$$\Phi_{\pi A}(A,B) = \hat{H}_{\pi B} + \sum_{k=1}^{N}\hat{\pi}_B(\sigma_{Bk})\cdot H_{\pi A}(\sigma_{Ai}|\sigma_{Bk}) + \\ +\sum_{i=1}^{N}\sum_{k=1}^{N}\hat{\pi}_B(\sigma_{Bk})\cdot\pi_A(\sigma_{Ai}|\sigma_{Bk})\cdot\left[\beta F_A\left(A\middle|B,\sigma_{Ai},\sigma_{Bk}\right)+\alpha\ln F_A\left(A\middle|B,\sigma_{Ai},\sigma_{Bk}\right)\right]+ \\ +\gamma\sum_{i=1}^{N}\sum_{k=1}^{N}\gamma_k\cdot\hat{\pi}_B(\sigma_{Bk})\pi_A\left(\sigma_{Ai}\middle|\sigma_{Bk}\right), \tag{3}$$

here

$$\hat{H}_{\pi B} = -\sum_{k=1}^{N}\hat{\pi}_B(\sigma_{Bk})\ln\hat{\pi}_B(\sigma_{Bk}) \tag{4}$$

is an estimation of the unconditional entropy of the subject B by the subject A;

$$H_{\pi A}\left(\sigma_{Ai}\middle|\sigma_{BK}\right) = -\sum_{i=1}^{N}\pi_A(\sigma_{Ai}|\sigma_{Bk})\ln\pi_A(\sigma_{Ai}|\sigma_{Bk}). \tag{5}$$

We have taken into account the normalizing condition:

$$\sum_{i=1}^{N} \pi_A(\sigma_{Ai} | \sigma_{Bk}) = 1; \ \forall k \in \overline{1, N}.$$

The function $\pi_A(A|B, \sigma_{Ai}, \sigma_{Bk})$ can be, in particular, the function of the mutual utility, in the given case, the utility of B for A. Although, mostly we talk about an individual utility of A, in the presence of B.

The expression within the brackets in the second summation member is the cognitive function of the subject A.

Let us realize the recursive scheme in this problem. Presumably $\pi_A(\sigma_{Ai}, \sigma_{Bk}) = \pi_A(\sigma_{Ai}t; \sigma_{Bk}t - 1)$, that is the function of the preferences distribution which depends on the preferences of the subject A at the moment of t and the preferences of the subject B at the moment of $t - 1$.

Let it be fulfilled relationship

$$\pi_A(\sigma_{Ai}t; \sigma_{Bk}t - 1) = \hat{\pi}_B(\sigma_{Bk}t - 1) \cdot \pi_A(\sigma_{Ai}t | \sigma_{Bk}t - 1) \tag{6}$$

then

$$\begin{aligned} H_{\pi At, t-1} &= -\sum_{i=1}^{N} \sum_{k=1}^{N} \hat{\pi}_B(\sigma_{Bk}t - 1) \cdot \pi_A(\sigma_{Ai}t | \sigma_{Bk}t - 1) \left[\ln \hat{\pi}_B(\sigma_{Bk}t - 1) + \ln \pi_A(\sigma_{Ai}t | \sigma_{Bk}t - 1) \right] = \\ &= H_{\pi Bt-1} + \sum_{k=1}^{N} \pi_B(\sigma_{Bk}t - 1) \cdot H_{\pi At, t-1}(A, t | B, t - 1), \end{aligned} \tag{7}$$

where

$$H_{\pi At, t-1} = -\sum_{i=1}^{N} \pi_A(\sigma_{Ai}t | \sigma_{Bk}t - 1) \ln \pi_A(\sigma_{Ai}t | \sigma_{Bk}t - 1). \tag{8}$$

Let us designate the cognitive function

$$F_{A_i|B_k}(t, t-1) = \beta F_A\left(A | B, \sigma_{Ai}t, \sigma_{Bk}t - 1\right) + \alpha \ln F_A\left(A | B, \sigma_{Ai}t, \sigma_{Bk}t - 1\right). \tag{9}$$

Then we can write down the functional of the recursive model for A in the view of

$$\begin{aligned} \Phi_{\pi A}(A, t, B, t-1) &= \hat{H}_{\pi Bt-1} - \sum_{k=1}^{N} \sum_{i=1}^{N} \hat{\pi}_B(\sigma_{Bk}t - 1) \cdot \pi_A(\sigma_{Ai}t | \sigma_{Bk}t - 1) \times \\ &\times \ln \pi_A(\sigma_{Ai}t | \sigma_{Bk}t - 1) + \sum_{i=1}^{N} \sum_{k=1}^{N} \hat{\pi}_B(\sigma_{Bk}t - 1) \pi_A\left(\sigma_{Ai}t | \sigma_{Bk}t - 1\right) \cdot F_{Ai, Bk}(t, t-1) + \\ &+ \gamma \sum_{i=1}^{N} \sum_{k=1}^{N} \gamma_{B, t-1} \hat{\pi}_B(\sigma_{Bk}t - 1) \times \pi_A(\sigma_{Ai}t | \sigma_{Bk}t - 1). \end{aligned} \tag{10}$$

The aggregation of the preferences in this functional has not been taken into account yet. Let us introduce the procedure for the aggregation. In our case the aggregation has a combined sense: the preferences of the 1st (objects) and 2nd (ratings) kind are engaged in the scheme.

$$\pi_A^{\Sigma}(\sigma_i,t)=\hat{\pi}_A(\sigma_{Ai},t)\xi(A|A,\sigma_{Ai}t)+\hat{\pi}_B(\sigma_{Ai},t)\xi(B|A,\sigma_i,t). \tag{11}$$

$$\pi_B^{\Sigma}(\sigma_i,t)=\hat{\pi}_A(\sigma_i,t)\xi(A|B,\sigma_i t)+\hat{\pi}_B(\sigma_i,t)\xi(B|B,\sigma_i,t). \tag{12}$$

Since $S_{aA} = S_{aB} = S_a$, it is possible to omit the indexes of "*A*" and "*B*" at the alternatives, i.e. $(\sigma_{ai} \to \sigma_i)$.

Here $\xi(A|A...)$, $\xi(B|B...)$ – *self ratings* estimates, that is themselves the estimation of their own ratings; $\xi(A|B...)$, $\xi(B|A...)$ – intersection ratings in the sight of the other subject. In a two level system with two subjects *A* and *B* the normalizing conditions yield

$$\xi(A|A...)=1-\xi(B|A...);\ \xi(B|B...)=1-\xi(A|B...). \tag{13}$$

The model of the 1st and 2nd types of the preferences aggregation brings a significant nonlinearity into the general scheme. It is possible to resolve this nonlinearity if one uses a recursive scheme. It has to be presupposed that different preferences are formed consequently at different moments in time.

This natural supposition brings a *consequential* method into a model of a subject's conscious work. In order to avoid exceeding complications we will realize the recursion for one step backwards. For this stage, it seams to be enough.

Let us organize the recursion at the objects preferences adding into the functional of $\Phi_{\pi A}$ and $\Phi_{\pi B}$ the corresponding summation members:

$$...+\mu\sum_{i=1}^{N}\sum_{k=1}^{N}\hat{\pi}_B(\sigma_{Bk},t-1)\pi_A(\sigma_{Ai},t|\sigma_{Bk},t-1)\times\ln\pi_A^{\Sigma}(\sigma_{Ai},t-1)+...\,, \tag{14}$$

$$...+\mu\sum_{i=1}^{N}\sum_{k=1}^{N}\hat{\pi}_A(\sigma_{Ai},t-1)\pi_B(\sigma_{Bk},t|\sigma_{Ai},t-1)\times\ln\pi_B^{\Sigma}(\sigma_{Bk},t-1)+...\,. \tag{15}$$

With respect to the remarks made let us find out the conditional distributions of the preferences of the 1st kind on conditions of

$$\frac{\partial\Phi_{\pi A}(A,t;B,t-1)}{\partial\pi_A(\sigma_i t|\sigma_k t-1)}=0; \tag{16}$$

$$\frac{\partial\Phi_{\pi B}(A,t;A,t-1)}{\partial\pi_B(\sigma_k t|\sigma_i t-1)}=0;\ \left(\forall i\in\overline{1,N};\ j\in\overline{1,N}\right). \tag{17}$$

We will get

$$\pi_A(\sigma_i t|\sigma_k t-1)=\frac{\left(\pi_A^{\Sigma}(\sigma_i,t-1)\right)^{\mu}\cdot\left(F_A(A|B,i,k,t)\right)^{\alpha}\cdot e^{\beta F_A(A|B,i,k,t)}}{\sum_{q=1}^{N}\left(\pi_A^{\Sigma}(\sigma_q t-1)\right)^{\mu}\left(F_A(A|B,q,k,t)\right)^{\alpha}\cdot e^{\beta F_A(A|B,q,k,t)}}, \tag{18}$$

$$\pi_B(\sigma_k t|\sigma_i t-1) = \frac{\left(\pi_B^{\Sigma}(\sigma_k,t-1)\right)^{\mu} \cdot \left(F_B(B|A,i,k,t)\right)^{\alpha} \cdot e^{\beta F_B(B|A,k,i,t)}}{\sum_{q=1}^{N}\left(\pi_B^{\Sigma}(\sigma_q t-1)\right)^{\mu}\left(F_B(B|A,q,k,t)\right)^{\alpha} \cdot e^{\beta F_B(B|A,q,i,t)}}. \tag{19}$$

In the formulae (11) and (12) the unconditional distributions of $\pi_A(\sigma_i, t)$ and $\pi_B(\sigma_i, t)$ are formed by the formulae

$$\pi_A(\sigma_i,t) = \sum_{k=1}^{N} \pi_B(\sigma_{k,}t-1)\cdot \pi_A(\sigma_i t|\sigma_{k,}t-1), \tag{20}$$

$$\pi_B(\sigma_k,t) = \sum_{i=1}^{N} \pi_A(\sigma_{i,}t-1)\cdot \pi_B(\sigma_k t|\sigma_{i,}t-1). \tag{21}$$

In accordance with the formulae of the aggregation (11) and (12) it should be pointed where there coming out the functions of the ratings preferences from.

Let us notify that, probably, it is possible to unite the two functional of $\{\Phi_{A\pi}, \Phi_{A\xi}\}$ and $\{\Phi_{B\pi}, \Phi_{B\xi}\}$ in pairs.

Let us consider the next functional:

$$\begin{gathered}\Phi_{A\xi,t,t-1} = -\xi\left(A|A,t...\right)\ln\xi\left(A|A,t...\right) - \xi\left(B|A,t...\right)\ln\xi\left(B|A,t...\right) + \\ +\alpha_{\xi}\cdot\left[\xi\left(A|A,t...\right)\ln\xi\left(A|A,t-1...\right)\cdot\varphi\left(\rho,\pi_{A,t-1}\right) + \right. \\ \left. +\xi\left(B|A,t...\right)\ln\xi\left(B|A,t-1\right)\psi\left(\rho,\pi_{B,t-1}\right)\right] + \beta_{\xi}\left[\xi\left(A|A,t...\right)\bar{\mathrm{U}}\left(A\to A,t...\right) + \right. \\ \left. +\xi\left(B|A,t...\right)\bar{\mathrm{U}}\left(B\to A,t\right)\right] + \gamma_{\xi}\left[\xi\left(A|A,t...\right) + \xi\left(B|A,t...\right)\right].\end{gathered} \tag{22}$$

Here α_ξ and β_ξ – endogenous parameters; γ_ξ – Lagrange multiplier. At $\alpha_\xi = 1$ the first three summation members represent a recursive variant of Kullback information [16]. The values $\bar{U}(A \to A,t...)$; $\bar{U}(B \to A,t...)$ represent utual expected utilities: $\bar{U}(A \to A,t...)$ – self-utility of A; $\bar{U}(B \to A,t...)$ – utility of B for A at the moment t. The sense of the multipliers φ and ψ will be described later when a problem of modeling a *conflict getting worse* is considered.

We will reflect the above mentioned tendencies with the help of the coefficient of correlation by Pearson ρ for the objects preferences: where $-1 \le \rho(\pi_A, \pi_B, t) \le +1$; also entropies of distributions $H_{A\pi}$ and $H_{B\pi}$. $\overline{H}_A = H_{A\pi} / H_{A\max}$, $\overline{H}_B = H_{B\pi} / H_{B\max}$.

Canonical ratings distributions, corresponding to functional (22), that is the solutions of the equations

$$\frac{\partial\Phi_{A\xi t,t-1}}{\partial\xi(A|A,t,...)} = 0; \tag{23}$$

$$\frac{\partial\Phi_{A\xi t,t-1}}{\partial\xi(B|A,t,...)} = 0, \tag{24}$$

also for the analogous functional $\Phi_{B\xi t,\,t-1}$, the bearer of which is the subject B, of the equations

$$\frac{\partial \Phi_{B\xi t,t-1}}{\partial \xi(B|B,t,...)} = 0; \tag{25}$$

$$\frac{\partial \Phi_{B\xi t,t-1}}{\partial \xi(A|B,t,...)} = 0, \tag{26}$$

are given with functions:

$$\xi(A|A,t...) = \frac{\varphi_A\left(\rho,\overline{H}_{A,t-1}\right)\left(\xi\left(A|A,t-1...\right)\right)^{\alpha_\xi}\cdot e^{\beta_\xi \overline{U}(A\to A,t...)}}{\left(\begin{array}{l}\varphi_A\left(\rho,\overline{H}_{A,t-1}\right)\xi\left(A|A,t-1...\right)^{\alpha_\xi}\cdot e^{\beta_\xi \overline{U}(A\to A,t)}+\\ +\psi_A\left(\rho,\overline{H}_{B,t-1}\right)\left(\xi\left(B|A,t-1...\right)^{\alpha_\xi}\cdot e^{\beta_\xi \overline{U}(B\to A,t...)}\right)\end{array}\right)}, \tag{27}$$

$$\xi(B|A,t...) = \frac{\psi_A\left(\rho,\overline{H}_{B,t-1}\right)\left(\xi\left(B|A,t-1...\right)\right)^{\alpha_\xi}\cdot e^{\beta_\xi \overline{U}(B\to A,t...)}}{\left(\begin{array}{l}\varphi_A\left(\rho,\overline{H}_{A,t-1}\right)\xi\left(A|A,t-1...\right)^{\alpha_\xi}\cdot e^{\beta_\xi \overline{U}(A\to A,t)}+\\ +\psi_A\left(\rho,\overline{H}_{B,t-1}\right)\left(\xi\left(B|A,t-1...\right)^{\alpha_\xi}\cdot e^{\beta_\xi \overline{U}(B\to A,t...)}\right)\end{array}\right)}, \tag{28}$$

$$\xi(B|B,t...) = \frac{\psi_B\left(\rho,\overline{H}_{B,t-1}\right)\left(\xi\left(B|B,t-1...\right)\right)^{\alpha_\xi}\cdot e^{\beta_\xi \overline{U}(B\to B,t...)}}{\left(\begin{array}{l}\varphi_B\left(\rho,\overline{H}_{A,t-1}\right)\xi\left(A|B,t-1...\right)^{\alpha_\xi}\cdot e^{\beta_\xi \overline{U}(A\to B,t)}+\\ +\psi_B\left(\rho,\overline{H}_{B,t-1}\right)\left(\xi\left(B|B,t-1...\right)^{\alpha_\xi}\cdot e^{\beta_\xi \overline{U}(B\to B,t...)}\right)\end{array}\right)}, \tag{29}$$

$$\xi(A|B,t...) = \frac{\varphi_B\left(\rho,\overline{H}_{B,t-1}\right)\left(\xi\left(A|B,t-1...\right)\right)^{\alpha_\xi}\cdot e^{\beta_\xi \overline{U}(A\to B,t...)}}{\left(\begin{array}{l}\varphi_B\left(\rho,\overline{H}_{B,t-1}\right)\xi\left(A|B,t-1...\right)^{\alpha_\xi}\cdot e^{\beta_\xi \overline{U}(A\to B,t)}+\\ +\psi_B\left(\rho,\overline{H}_{B,t-1}\right)\left(\xi\left(B|B,t-1...\right)^{\alpha_\xi}\cdot e^{\beta_\xi \overline{U}(B\to B,t...)}\right)\end{array}\right)}. \tag{30}$$

In these formulae, as well as in the functional (22), the functions of φ_A, ψ_A, φ_B, ψ_B have been used which are being introduced in order to represent the mutual influence of A and B in conditions of a conflict getting worse for the two cases: a *horizontal* or *professional conflict*, when A and B are positioned at the same level; and a *vertical conflict*, when A and B are situated at different levels of the hierarchical system. The represented model, of course, is quite schematically based.

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ZARZĄDZANIE HIERARCHICZNYM AKTYWNYM SYSTEMEM NA PODSTAWIE PARADYGMATU ENTROPII ANALIZY SUBIEKTYWNEJ

Streszczenie

Konflikty rozkładów preferencji, zostały opracowane na podstawie modelu konfliktów. Zaproponowano klasyfikację konfliktów, które w znacznym stopniu odzwierciedlają istniejący stan wiedzy w tej dziedzinie. Uważa się, że przechodzenie konfliktów z jednego etapu do drugiego jest połączone z przezwyciężeniem pewnych progów entropii. Omówiona została dynamika konfliktów, konflikty interpersonalne i intrapersonalne.

Autorzy omawiają zadania kontroli hierarchicznej systemu, podają niektóre środki diagnostyczne i profilaktyczne rozwoju konfliktu. Kontrola na danym etapie chłodnego konfliktu ma wpływ na konkurencję i często konkurencja, opozycja zatrzymuje destrukcyjne konflikty. Subiektywna analiza dostarcza sposobu na sformalizowania chłodnego konfliktu, oraz przejścia do gorącego konfliktu − gdy „muzy milczą" to „armaty grzmią". Przedstawiono również modele dynamiki procesów umysłowych w ramach paradygmatu entropii.

Słowa kluczowe: systemy aktywne, rozkłady preferencji, konflikty interpersonalne, dynamika konfliktu.