Pawlak's Conflict Model: Directions of Development

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Contents

***On conflicts*, International Journal of Man-Machine Studies, 21, 127–134, 1984** – a model to describe the structure of conflict was proposed by Professor Zdzisław Pawlak.
The issue was developed by Professor Pawlak in the papers

- *O konfliktach*, PWN, Warszawa, (1987)
- *Anatomy of conflicts*, Bulletin of the European Association for Theoretical Computer Science, 50, 234–247, (1993)
- *An inquiry anatomy of conflicts*, Journal of Information Sciences 109, 65–78, (1998)
- *Some remarks on conflict analysis*, European Journal of Operational Research 166, 649–654, (2005)

The parties involved in the conflict are called ***agents***.

Each agent expresses his opinion by one of three values:
-1 means, that an agent is against, 0 neutral toward the issue 1 favorable.

Knowledge about conflict situation is written in the form of table – the entries are the values that were uniquely assigned to each agent and an issue. This type of table is an example of an information system $S = (U, A)$.

In the case of the Pawlak's conflict model elements of the universe U are agents, A is a set of issues, and the set of values of $a \in A$ is equal $V^a = \{-1, 0, 1\}$. The value $a(x)$, where $x \in U, a \in A$ is opinion of agent x about issue a.

For each $a \in A$ function $\phi_a : U \times U \to \{-1, 0, 1\}$ is defined:

$$\phi_a(x,y) = \begin{cases} 1 & \text{if } a(x)a(y) = 1 \text{ or } x = y, \\ 0 & \text{if } a(x)a(y) = 0 \text{ and } x \neq y, \\ -1 & \text{if } a(x)a(y) = -1. \end{cases}$$

Relations

Then over $U \times U$ three relations are defined: R_a^+ alliance, R_a^0 neutrality, R_a^- conflict, that express the relations between agents:

$$\begin{array}{ll} R_a^+(x,y) & \text{if and only if } \phi_a(x,y) = 1, \\ R_a^0(x,y) & \text{if and only if } \phi_a(x,y) = 0, \\ R_a^-(x,y) & \text{if and only if } \phi_a(x,y) = -1. \end{array}$$

Relation R_a^+ is an equivalence relation. Each equivalence class of alliance relation R_a^+ is called ***coalition*** on a.

Distance between agents

In order to evaluate views between agents x and y with respect to the set of issues $B \subseteq A$ a function of distance between agents $\rho_B^* : U \times U \to [0, 1]$ is defined

$$\rho_B^*(x, y) = \frac{\sum_{a \in B} \phi_a^*(x,y)}{card\{B\}},$$

where

$$\phi_a^*(x, y) = \frac{1 - \phi_a(x, y)}{2} = \begin{cases} 0 & \text{if } a(x)a(y) = 1 \text{ or } x = y, \\ 0.5 & \text{if } a(x)a(y) = 0 \text{ and } x \neq y, \\ 1 & \text{if } a(x)a(y) = -1. \end{cases}$$

The function of distance between agents for the set of all issues $B = A$ is written in short as ρ.

Coalition

A pair $x, y \in U$ is said to be:

- allied $R^+(x, y)$, if $\rho(x, y) < 0.5$,
- in conflict $R^-(x, y)$, if $\rho(x, y) > 0.5$,
- neutral $R^0(x, y)$, if $\rho(x, y) = 0.5$.

Set $X \subseteq U$ is a coalition if for every $x, y \in X$, $R^+(x, y)$ and $x \neq y$.

Each agent has the strength, that is expressed in the form of non-negative real number $\mu : U \rightarrow [0, \infty)$. Each agent distributes his forces against his enemies according to a chosen strategy and knowledge of the situation.

Strategy

A *strategy* is defined as a function $\lambda : U \times U \rightarrow [0, \infty)$ that assigns a non-negative real number to each pair of agents x, y. It is reasonable to assume that for every x, y:

$$\text{if } \rho(x, y) \leqslant 0.5 \text{ then } \lambda(x, y) = 0,$$

$$\sum_{y \in E_x} \lambda(x, y) \leqslant \mu(x),$$

where E_x is the set of all enemies of x, i.e., $E_x = \{y \in U : \rho(x, y) > 0.5\}$.

Professor Pawlak has defined a particularly important strategy, in which each agent has enough strength to destroy all of his enemies. A strategy of intimidation is a strategy λ that fulfills the conditions:

$$\forall_{x \in U} \quad \sum_{y \in E_x} \lambda(x, y) = \mu(x),$$

$$\forall_{x, y \in U} \quad \lambda(x, y) = \lambda(y, x).$$

The Middle East conflict - from the paper Z. Pawlak, *An inquiry anatomy of conflicts*, Journal of Information Sciences 109, (1998)

In the example there are six agents $U = \{1, 2, 3, 4, 5, 6\}$

1 - Israel, **2** - Egypt, **3** - Palestinians, **4** - Jordan, **5** - Syria, **6** - Saudi Arabia

and five issues $A = \{a, b, c, d, e\}$

a - autonomous Palestinian state on the West Bank and Gaza
b - Israeli military outpost along the Jordan River
c - Israeli retains East Jerusalem
d - Israeli military outposts on the Golan Heights
e - Arab countries grant citizenship to Palestinians who choose to remain within their borders

The relationship of each agent to a specific issue is as follows

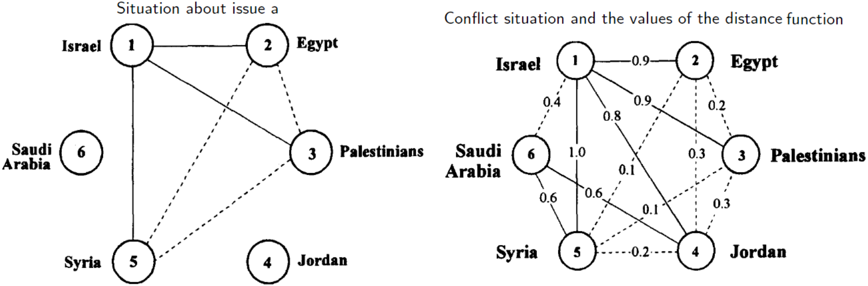
U	a	b	c	d	e
1	−	+	+	+	+
2	+	0	−	−	−
3	+	−	−	−	0
4	0	−	−	0	−
5	+	−	−	−	−
6	0	+	−	0	+

This can be easily illustrated by a graph.

Employing the distance function for the Middle East conflict we get

	1	2	3	4	5	6
1						
2	0.9					
3	0.9	0.2				
4	0.8	0.3	0.3			
5	1.0	0.1	0.1	0.2		
6	0.4	0.5	0.5	0.4	0.6	

The Middle East conflict



We have two coalitions $\{1, 6\}$ and $\{2, 3, 4, 5\}$.

Around 1996, Professor Skowron and Doctor Deja proposed conflict model, which is an enhancement of the model of Professor Pawlak. This concept is described in the papers

- Deja, R.: *Conflict analysis*, Proceedings of the fourth international workshop on rough sets, fuzzy sets and machine discovery, The University of Tokyo, 6-8 Nowember, 118–124, (1996)
- Deja, R.: *Conflict analysis*, Proceedings of the 7th European Congress on Intelligent Techniques & Soft Computing, Aachen, Germany, September 13-16, (1999)
- Deja, R.: *Conflict analysis*, Rough Sets; New Developments. In: Polkowski L. (eds.), Studies in Fussiness and Soft Computer Science, Physica-Verlag, (2000)
- Deja, R.: *Zastosowanie teorii zbiorów przybliżonych w analizie konfliktów*, Instytut Podstaw Informatyki Polskiej Akademii Nauk, Rozprawa doktorska, promotor: A. Skowron (2000)
- Skowron, A., Deja, R.: *On Some Conflict Models and Conflict Resolutions*, Romanian Journal of Information Science and Technology 3(1-2), 69–82, (2002)
- Deja, R.: *Conflict analysis*, Int. J. Intell. Syst., 17, 2, 235–253, (2002)

The reasons for introducing a new conflict model

- The assumption that the issues the agents vote represent the issues each agent takes care of causing that the model can be applied in very few real situations.
- A set of the attribute's values may be too limited in many real situations.
- In the Pawlak model the reason for the conflict cannot be determined - views on the issues to vote are consequences of the decision taken, based on the local issues, the current state and some background knowledge that are the real cause of the conflict.

The main assumptions of the model

- The conflict between agents is the consequence of the limited resources which are available to agents in a situation. If the number of resources is insufficient to attain agents' goals it often comes into the conflicts.
- In the proposed model, the fact was taken into consideration that any agent is describing the situation in its own way. The manner of understanding the same world by each agent can be completely different. A reflection of this assumption in the mathematical model is that for each agent a separate information system is assigned. It was assumed that the sets of attributes of different agents are pairwise disjoint.

Description of the model

- Knowledge of the agent's attitude to the conflict situation is represented in a information system.
- For each information system a target function, that determines a subjective evaluation score to each state, is defined.
- Constraints, that come from the bound on the number of resources and describe some dependencies among local states of agents, are introduced. Constraints restrict the set of possible situations to admissible situations.
- The global situations are evaluated. The score assigned to each situation can reflect the agents preferences (subjective states evaluation) or the expert judgement - who takes into account the global good.
- Three types of conflicts are distinguished
    - local conflict - that arises from the low level of subjective evaluation of the current state,
    - global conflict (based on an expert evaluation) - indicates the existence of a situation which is not preferable for the global good,
    - global conflict (based on agents preferences) - indicates that the current situation is not preferred by most of the agents.
- The concepts of conflict, that are defined above, are the basis for investigation of the most fundamental problem - the possibility to achieve *the consensus*.

Around 2009, Professor Wakulicz-Deja and Doctor Przybyła-Kasperek proposed conflict model, which is also an extension of the model of Professor Pawlak. This concept is described in the papers

- Wakulicz-Deja A., Przybyła-Kasperek M.: *Hierarchical Multi-Agent System*, Recent Advances in Intelligent Information Systems, Academic Publishing House EXIT, 615-628, (2009)
- Wakulicz-Deja A., Przybyła-Kasperek M.: *Global decisions Taking on the Basis of Multi-Agent System with a Hierarchical Structure and Density-Based Algorithm*, CS&P, Uniwersytet Warszawski, 616-627, (2009)
- Wakulicz-Deja A., Przybyła-Kasperek M.: *Multi-Agent Decision Taking System*, Fundamenta Informaticae 101(1-2), 125-141, (2010)
- Wakulicz-Deja A., Przybyła-Kasperek M.: *Application of the method of editing and condensing in the process of global decision-making*, Fundamenta Informaticae 106 (1), 93-117, (2011)
- Przybyła-Kasperek M., Wakulicz-Deja A.: *Application of decision rules, generated on the basis of local knowledge bases, in the process of global decision-making*, Intelligent Decision Technologies Smart Innovation, Systems and Technologies, Vol. 1, Part 2, 375-388, (2012)
- Przybyła-Kasperek M., Wakulicz-Deja A.: *Application of reduction of the set of conditional attributes in the process of global decision-making*, Fundamenta Informaticae 122 (4), 327-355, (2013)
- Przybyła-Kasperek M., Wakulicz-Deja A.: *Global decision-making system with dynamically generated clusters*, Information Sciences Volume 270, 172–191 (2014)
- Przybyła-Kasperek M., Wakulicz-Deja A.: *A dispersed decision-making system - The use of negotiations during the dynamic generation of a system's structure*, Information Sciences, Volume 288, 194–219 (2014)
- Przybyła-Kasperek M., Wakulicz-Deja A.: *Global decision-making in multi-agent decision-making system with dynamically generated disjoint clusters*, Applied Soft Computing, 40, 603–615 (2016)
- Przybyła-Kasperek M., Wakulicz-Deja A.: *The strength of coalition in a dispersed decision support system with negotiations*, European Journal of Operational Research, 252, 947–968 (2016)

The reasons for introducing a new conflict model

- The goal is to make decisions based on dispersed knowledge that is stored in many local decision tables. These tables are given in advance and collected by different units for example in different medical centers. We do not assume that the sets of conditional attributes or the universe of different local decision tables are disjoint or equal.
- The model of Professor Pawlak can not be directly applied, because we are dealing with a set of decision tables - not just one information system.
- The model of Professor Skowron and Doctor Deja can not be applied, because in order to resolve conflicts the Boolean reasoning is used there and the algorithm has exponential pessimistic execution time. The identification of constraints in the considered dispersed situation is not possible. In addition, the assumption that the sets of conditional attributes of all decision tables must be disjoint is not fulfilled.

The main assumptions of the model

- We assume that knowledge is stored in several decision tables. There are a set of resource agents, one agent has access to one decision table. We combine resource agents, that are similar, in some specified sense, into a group.
- System has a hierarchical structure. For each group of agents a superordinate agent is defined - a synthesis agent. The synthesis agent has access to knowledge that is the result of the process of inference that is carried out by the resource agents that belong to its subordinate group.
- Based on local decisions taken by synthesis agents, global decisions are generated using certain fusion methods and methods of conflict analysis.

The first approach was proposed in the papers

- Wakulicz-Deja A., Przybyła-Kasperek M.: *Hierarchical Multi-Agent System*, Recent Advances in Intelligent Information Systems, Academic Publishing House EXIT, 615-628, (2009)
- Wakulicz-Deja A., Przybyła-Kasperek M.: *Global decisions Taking on the Basis of Multi-Agent System with a Hierarchical Structure and Density-Based Algorithm*, CS&P, Uniwersytet Warszawski, 616-627, (2009)
- Wakulicz-Deja A., Przybyła-Kasperek M.: *Multi-Agent Decision Taking System*, Fundamenta Informaticae 101(1-2), 125-141, (2010)

Description of the model

- Resource agents taking decisions on the basis of common conditional attributes form a group of agents called a cluster.
- Based on the decision tables of the resource agents from one cluster an aggregated decision table of synthesis agent is created. The aggregated objects are created by combining objects from the decision tables of the resource agents for which the values of the decision attribute and common conditional attributes are equal.
- Global decisions are taken based on the decisions generated using the aggregated decision tables and the DBSCAN algorithm.

The second approach was proposed in the papers

- Wakulicz-Deja A., Przybyła-Kasperek M.: *Application of the method of editing and condensing in the process of global decision-making*, Fundamenta Informaticae 106 (1), 93-117, (2011)
- Przybyła-Kasperek M., Wakulicz-Deja A.: *Application of decision rules, generated on the basis of local knowledge bases, in the process of global decision-making*, IDT, 1(2), 375-388, (2012)
- Przybyła-Kasperek M., Wakulicz-Deja A.: *Application of reduction of the set of conditional attributes in the process of global decision-making*, Fundamenta Informaticae 122 (4), 327-355, (2013)

Description of the model

The same methods as in the first approach are used, however, additionally the decision tables of the resource agents are subjected to a certain transformation.

- In the first paper, the method of editing and condensing were used on the decision tables of the resource agents.
- In the second paper, based on the decision tables of the resource agents decision rules, using rough set theory, are generated. Then, in a single cluster, these rules are aggregated.
- In the third article, from each decision tables of the resource agents unnecessary attributes are removed.

The third approach was proposed in the papers

- Przybyła-Kasperek M., Wakulicz-Deja A.: *Global decision-making system with dynamically generated clusters*, Information Sciences Volume 270, 172–191 (2014)
- Przybyła-Kasperek M., Wakulicz-Deja A.: *Global decision-making in multi-agent decision-making system with dynamically generated disjoint clusters*, Applied Soft Computing, 40, 603–615 (2016)

Description of the model

- The aim is to identify homogeneous groups of resource agents. The agents who agree on the classification into the decision classes for a test object will be combined in a group.
- The modified definitions of relations of friendship and conflict as well as the method for determining the intensity of the conflict, which were introduced by Professor Pawlak, are used. Relations between agents are defined by their views on the classification of the test object to the decision classes.
- In the first step of the process of clusters creating for each resource agent ag_i a vector of probabilities that reflects the classification of the test object is generated. Then, based on this vector, the vector of ranks $[r_{i,1}(x), \ldots, r_{i,c}(x)]$, where $c = card\{V^d\}$ is generated.

Description of the model

We define the function $\phi^x_{v_j}$ for the test object x and each value of the decision attribute $v_j \in V^d$; $\phi^x_{v_j} : Ag \times Ag \to \{0,1\}$

$$\phi^x_{v_j}(ag_i, ag_k) = \begin{cases} 0 & \text{if } r_{i,j}(x) = r_{k,j}(x) \\ 1 & \text{if } r_{i,j}(x) \neq r_{k,j}(x) \end{cases}$$

where $ag_i, ag_k \in Ag$.

We also define the intensity of conflict between agents using a function of the distance between agents. We define the distance between agents ρ^x for the test object x: $\rho^x : Ag \times Ag \to [0,1]$

$$\rho^x(ag_i, ag_k) = \frac{\sum_{v_j \in V^d} \phi^x_{v_j}(ag_i, ag_k)}{card\{V^d\}},$$

where $ag_i, ag_k \in Ag$.

We say that agents $ag_i, ag_k \in Ag$ are in a friendship relation due to the object x, which is written $R^+(ag_i, ag_k)$, if and only if $\rho^x(ag_i, ag_k) < 0.5$. Agents $ag_i, ag_k \in Ag$ are in a conflict relation due to the object x, which is written $R^-(ag_i, ag_k)$, if and only if $\rho^x(ag_i, ag_k) \geqslant 0.5$.

Disjoint clusters of resource agents remaining in the friendship relations

The approach that was considered in the paper:
Przybyła-Kasperek M., Wakulicz-Deja A.: *Global decision-making in multi-agent decision-making system with dynamically generated disjoint clusters*, Applied Soft Computing, 40, 603–615 (2016)

Initially, each resource agent is treated as a separate cluster.

1. One pair of different clusters is selected for which the distance reaches a minimum value. If the selected value of the distance is less than 0.5, then agents from the selected pair of clusters are combined into one new cluster. Otherwise, the clustering process is terminated.
2. After defining a new cluster, the value of the distance between the clusters are recalculated. Let $\rho^x : 2^{Ag} \times 2^{Ag} \rightarrow [0, 1]$, let D_i be a cluster formed from the merger of two clusters $D_i = D_{i,1} \cup D_{i,2}$

$$\rho^x(D_i, D_j) = \begin{cases} \frac{\rho^x(D_{i,1}, D_j) + \rho^x(D_{i,2}, D_j)}{2} & \text{if } \rho^x(D_{i,1}, D_j) < 0.5 \\ & \text{and } \rho^x(D_{i,2}, D_j) < 0.5 \\ \max\{\rho^x(D_{i,1}, D_j), \rho^x(D_{i,2}, D_j)\} & \text{if } \rho^x(D_{i,1}, D_j) \geqslant 0.5 \\ & \text{or } \rho^x(D_{i,2}, D_j) \geqslant 0.5 \end{cases}$$

Not disjoint clusters of resource agents remaining in the friendship relations

The approach that was considered in the paper:
Przybyła-Kasperek M., Wakulicz-Deja A.: *Global decision-making system with dynamically generated clusters*, Information Sciences Volume 270, 172–191 (2014)

The cluster is the maximum, due to the inclusion relation, set of resource agents such that $\forall_{ag_i, ag_k \in X} \ R^+(ag_i, ag_k)$.

The fourth approach was proposed in the paper
Przybyła-Kasperek M., Wakulicz-Deja A.: *A dispersed decision-making system - The use of negotiations during the dynamic generation of a system's structure*, Information Sciences, Volume 288, 194–219 (2014)

Description of the model

The definition of the distance function, which was given in the previous paper is used. But now in the process of clusters creating a negotiation stage occurs. The definitions of the relations between agents are also changed, now there are three types of relations - friendship, conflict and neutrality.

Let p be a real number, which belongs to the interval $[0, 0.5)$.
We say that agents $ag_i, ag_k \in Ag$ are in a friendship relation due to the object x, which is written $R^+(ag_i, ag_k)$, if and only if

$$\rho^x(ag_i, ag_k) < 0.5 - p$$

Agents $ag_i, ag_k \in Ag$ are in a conflict relation due to the object x, which is written $R^-(ag_i, ag_k)$, if and only if

$$\rho^x(ag_i, ag_k) > 0.5 + p$$

Agents $ag_i, ag_k \in Ag$ are in a neutrality relation due to the object x, which is written $R^0(ag_i, ag_k)$, if and only if

$$0.5 - p \leqslant \rho^x(ag_i, ag_k) \leqslant 0.5 + p$$

Description of the model

- The first step is to define the initial group of agents remaining in the friendship relation. The initial cluster is the maximum, due to the inclusion relation, subset of resource agents $X \subseteq Ag$ such that $\forall_{ag_i, ag_k \in X} \quad R^+(ag_i, ag_k)$.
- After the first stage we obtain a set of initial clusters and a set of agents which are not included in any cluster. In the second step, agents which remained undecided (those which are in neutrality relation) play a key role. As it is known the goal of negotiation process is to reach a compromise by accepting some concessions by the parties involved in a conflict situation.
- In the negotiation process, the intensity of the conflict is determined by using the generalized distance function.
- Then the agent without coalition is included to all initial clusters, for which the generalized distance does not exceed a certain threshold, which is set by the system's user. Also agents without coalition, for which the value of the generalized distance function does not exceed the threshold, are combined into a new cluster.

The fifth approach was proposed in the paper

Przybyła-Kasperek M., Wakulicz-Deja A.: *The strength of coalition in a dispersed decision support system with negotiations*, European Journal of Operational Research, 252, 947–968 (2016)

Description of the model

In this approach, a method of creating clusters is the same as in the previous approach but when the global decisions are taken the agents' weights are additionally calculated. Different methods of calculating the strength of a cluster was proposed:

- with respect to the number of component agents
- with respect to the decisiveness of agents
- with respect to the number of component agents and the decisiveness of agents
- with respect to the decisiveness-based cluster strength

All of the proposed methods were compared.

In this presentation, the conflict analysis model that was proposed by Professor Pawlak has been described.

The main extensions of this model that have been proposed in the literature are shown.

Professor Pawlak's model is simple, intuitive and very useful in the analysis of the complex nature of conflicts. The model has many applications and is inspiration for developing new approaches.