BUILDING AND VALIDATING METRICS OF COLLABORATIVE SYSTEMS

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Abstract. *The most encountered types of collaborative systems in knowledge-based economy are formalized and their characteristics are identified. Each collaborative system is analyzed from the point of view of inputs, states and outputs. Metrics for assessing the resources allocation in a banking system are built and validated by testing on real data. A genetic algorithm is implemented for building and validating metrics of collaborative systems.*

Keywords: collaborative systems, metrics, building, validating, genetic algorithms.

JEL Classification: P51.

REL Classification: 6D.

1. Formalization of collaborative systems in the knowledge-based economy

In (Oguz et all, 2010) is considered that in the knowledge-based economy, collaboration means more than two agents working together. It requires defining a shared goal and, in order to achieve this goal, the agents should create an agreement upon their ways of actions. The implementation of collaborative informatics systems in different activity fields facilitates the resolution of many citizens' problems.

A collaborative system is represented by:

- a lot of input messages, $I = \{i_1, i_2, \ldots, i_m\}$, which determine the conduct of activities and the development of process stages;
- a lot of states, $X = \{x_1, x_2, \ldots x_s\}$, that require actions, consumption of resources, operations, equipment, people;
- a lot of output messages, $E = \{e_1, e_2, \ldots e_n\}$, which accompany finished products and services.

The input and output messages consists of subsets of homogeneous messages in relation to one or more criteria.

A collaborative system is defined by the following elements (Ionescu, 1973):

$$\Sigma = (T, S, R, I, \Omega, X, E, \Gamma, F, \varphi, \eta),$$

where:

T – the time, represented by the lot of moments in which the system operates;

S – the space, represented by the set of locations where the system operates;

R – the resources, the lot of human, material and energy resources that contribute to activity achievement;

I – the set of values of input variable i;

Ω – the class of temporary evolutions allowed, $\Omega = \{\omega : T -> I\}$, $\omega = \{i(t) / t \in T, i(t) \in I\}$, $\Omega \neq \phi$;

X – the space of states, represented by the set of values of state variable x;

E – the set of values of output variable e;

Γ – the class of possible outputs, $\Gamma = \{\gamma : T -> E\}$, $\gamma = \{e(t) / t \in T, e(t) \in E\}$;

F – the work flows, the set of values of flow variable f;

φ – the transition function of the system, $\varphi : TxTxXx\Omega -> X$, $x(t) = \varphi(t;\tau;x;\omega)$;

η – the output function of the system, $\eta : TxX -> E$, $e(t) = \eta(t;x(t))$.

Figure 1 presents the components of a collaborative system and the relationships between them:

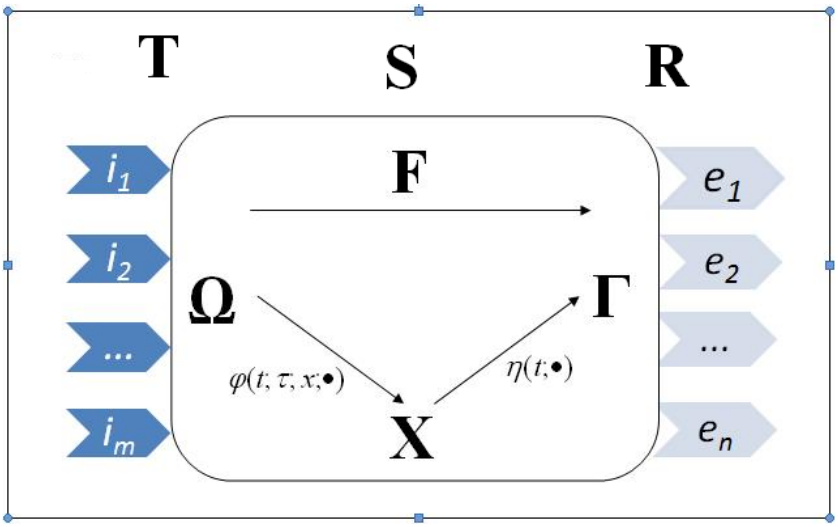

Fig. 1. The components of a collaborative system

In the knowledge-based economy, there are many types of collaborative systems, the must important being the collaborative banking systems, collaborative educational systems and collaborative systems in production.

In the machine-building industry are encountered the followings elements that define a collaborative production system: raw materials types, machine types, types of operations, types of finished products, and number of beneficiaries.

The collaborative production system, *SCP*, from the machine-building industry is represented by the following quintuple:

SCP = (NMAT, MMAS, KOPE, PPRO, BBEN),

where:

NMAT – the number of raw materials types;

MMAS – the number of machines types;

KOPE – the number of operations types;

PPRO – the number of finished products types;

BBEN – the number of beneficiaries.

A collaborative banking system, *SCB*, seen as finite state machine, is formalized as:

$SCB = (BC_1, BC_2, BC_3, BC_4, BC_5, BC_6)$,

where:

BC_1 – the input alphabet, containing an array of input messages that determine the conduct of activities and the coverage of process steps;

BC_2 – the output alphabet, defined as messages that accompany the services offered by the bank;

BC_3 – a finite and non-empty array of states that require action, consumption of resources, operations, equipment, people;

BC_4 – the initial state, element of BC_3;

BC_5 – the transition function $BC_5 : BC_3 \ x \ BC_1 -> BC_3 \ x \ BC_2$;

BC_6 – the output function.

Collaborative systems require the existence of such activities that need to be automated, in order to streamline the workflow within an organization. In a collaborative

banking system, any change in the workflow must be found in the corresponding rules and procedures.

2. Building metrics for assessing the resources allocation in a banking system

Metrics of collaborative systems represent mathematical models developed around an equation. Metrics use analytical expressions having the form: $y = f(x, z, w)$, where x, z and w are variables of influence factors, and y is the result variable (Ivan et all, 2004). A metric of collaborative systems must be characterized by the following properties: sensitivity, not compensatory character, not catastrophic character, representativeness (Ciurea, 2010a).

In a collaborative banking system, the agents are instructed to carry out other activities than those they currently realize. If the case in which a banking officer is on leave, his duties are handled by the customer account manager so that the system operate normally.

It is considered the indicator for assessing the level of specialization of an agent in a collaborative banking system, *ESA*, defined as follows:

$$ESA = AFP \times pe_1 + NFP \times pe_2,$$

where:

AFP – the number of activities from the job description, performed by an agent within a working day;

NFP – the number of activities not covered in the job descriptions that were made by the agent in a working day;

pe_1, pe_2 – weights associated to the number of activities realized ($pe_1 = 0.6$, $pe_2 = 0.4$).

In a collaborative system, the indicator for assessing the level of specialization of an agent has a value close to 1, since the agents are instructed to carry out activities other than those defined in the job description. In the classical system, each agent realizes only what is provided in the job description and is not trained to perform other tasks.

The decision makers responsible for the efficient allocation of human resources from a bank are the managers and directors of departments. There are situations in which certain jobs from the bank departments remain uncovered temporarily, and managers require the support from other departments regarding the allocation of existing human resources, until are found and hired people to fill those positions. There are identified relevant people within the bank departments that have the necessary knowledge and skills and are allocated on vacancies jobs.

Figure 2 presents the correct allocation of employees on vacancies jobs within a bank. The employee *AA* is assigned to the post *AA* that fits his skills and knowledge. Even if the job responsibilities are inadequate with those of the employee, the allocation is correct, based on the premise that no employee is fully compatible with the position held. The same correct allocation is presented in the case of the employee *BB*.

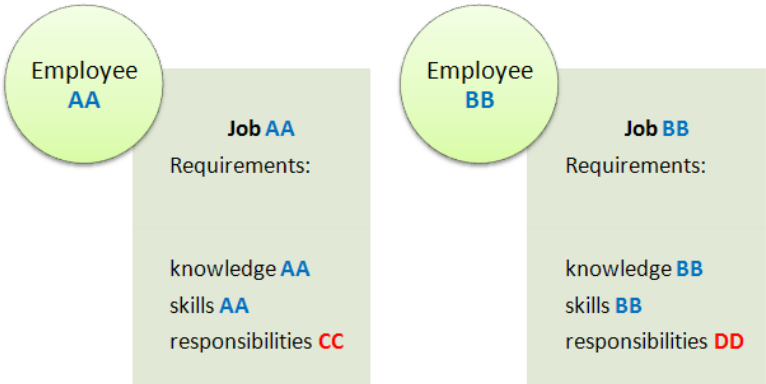

Fig. 2. The correct allocation of human resources in a collaborative banking system

In Figure 3 is shown the situation in which the employee *AA* was improperly assigned to the job *XX*, because the knowledge, skills and responsibilities of the job are quite different from those of the employee.

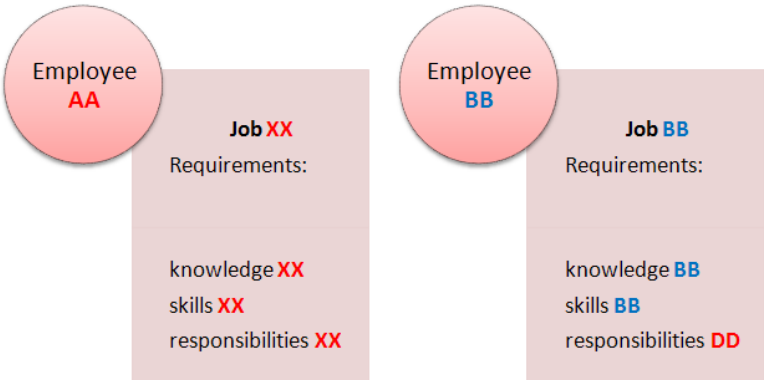

Fig. 3. The incorrect allocation of human resources in a collaborative banking system

The allocation should be made so that moving a person from a job to another does not adversely affect the bank's activity. The incorrect allocation of human resources on different jobs has dramatic consequences for the proper operation of the bank, but also on personal and professional development of individuals.

3. Metrics validation by testing on real data

The indicator for evaluating the efficiency of a bank officer, BO, is calculated as follows:

$$BO = \frac{ANP \times p_1}{AST \times p_2 + AHT \times p_3} \times AAM \times p_4,$$

where:

AST – average time for serving a client;

AHT – average time for waiting in line;

ANP – average number of clients waiting in line;

AAM – average amount of money traded by a client per unit time;

p_1, p_2, p_3, p_4 – weights, with $p_1 + p_2 + p_3 + p_4 = 1$.

For a bank in Romania the following results were obtained for the indicators *AST*, *AHT*, *ANP* and *AAM* in the case of 10 clients served:

Table 1. The values of indicators for a collaborative banking system

	Client 1	**Client 2**	**Client 3**	**Client 4**	**Client 5**	**Client 6**	**Client 7**	**Client 8**	**Client 9**	**Client 10**
AST	10	9	8.5	9.5	11	10.5	10	7.5	11.5	9.5
AHT	5	6	5.5	3.5	4	6.5	3	5	4.5	5.5
ANP	50	48	55	52	46	59	37	47	45	54
AAM	105	103	110	114	98	93	126	108	99	101

To calculate the indicator for evaluating the efficiency of a bank officer, there are considered the following values of the weights: $p_1 = 0.3$, $p_2 = 0.2$, $p_3 = 0.2$, $p_4 = 0.3$.

From Table 1 results that the average time for serving a client *AST = 9.7* minutes, the average time for waiting in line *AHT = 4.85* minutes, the average number of clients waiting in line *ANP = 49.3* and the average amount of money traded by a client per unit time *AAM = 105.7* RON. Results that the indicator for evaluating the efficiency of a bank officer, *BO = 161.16*, which means that the bank officer is better with *61.16%* than the level of efficiency required by the bank.

4. Genetic algorithm implementation for building and validating metrics

Collaborative informatics systems from the banking field differ one from each other by complexity of their components. The relative complexity of a banking informatics system, *RC*, is determined according to the relationship (Ciurea, 2010b):

$$RC = \frac{NCAI * \log_2 NCAI + NSIB * \log_2 NSIB}{(NCAI + NSIB) * \log_2 (NCAI + NSIB)},$$

where:

NCAI – the number of components associated with software applications integrated in the banking informatics system, with the property that *NCAI > 0* is a natural number, *NCAI Є N*.

NSIB – the number of modules forming the banking informatics system, where *NSIB > 0* is a natural number, *NSIB Є N*.

In Figure 4 is presented the 3D graphic of the function *RC(x, y)* $= \frac{x * \log_2 x + y * \log_2 y}{(x + y) * \log_2 (x + y)}$, where *x, y Є N*:

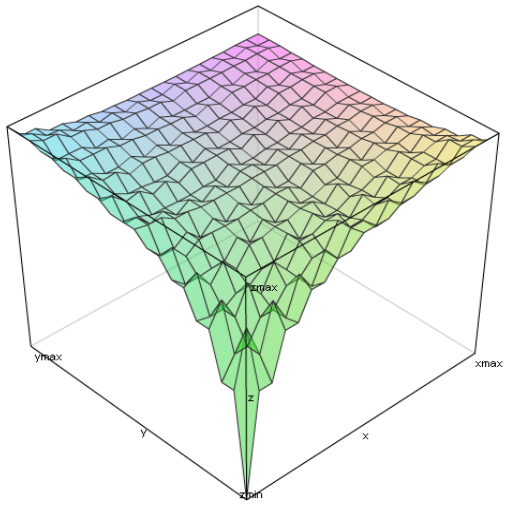

Fig. 4. The 3D graphic of the function *RC()*

A genetic algorithm was implemented in the CMS application, available at http://collaborative.ase.ro/teza, in order to determine the local minimum and maximum values of the *RC(x, y)* function, where *x, y Є R*. This algorithm objective is to determine the number of modules and components associated with software applications integrated in the banking informatics system for which the relative complexity is minimum or maximum.

Different genomes are created with elements in the interval 0-1, but the values are improved at each generation, so that the final values obtained are much closer to the values of maximum and minimum points of the function.

In Table 2 are presented the values obtained in three successive generations of the genetic algorithm.

Table 2. The values obtained with the genetic algorithm

Number of generations	Maximum point value	Minimum point value	RC() function value in the maximum point
1	0.94760	0.68387	-0.00785
2	0.98459	0.55019	-0.00225
3	0.99667	0.30934	-0.00048

Figure 5 shows the values of maximum and minimum points in the three generations of the algorithm. As seen from the graphic, the maximum point tends near to 1 and the minimum point decrease near to 0.3.

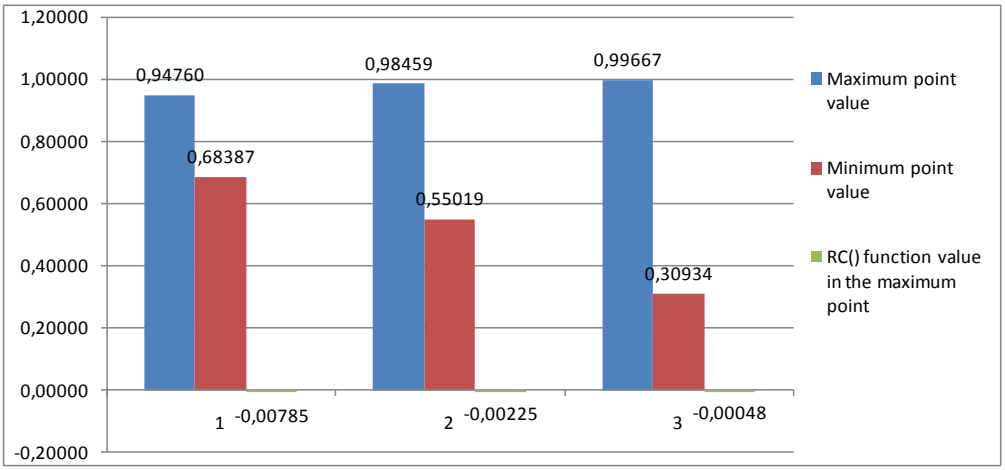

Fig. 5. The values of maximum and minimum points

The local maximum point value, *0.99667*, obtained with the help of the genetic algorithm, shows that the relative complexity of the banking informatics system is maximal when the number of components associated with software applications, *NCAI = 1*, and the number of modules forming the banking informatics system, *NSIB = 1*.

5. Conclusions

The metrics helps to make a quantitative analysis of the collaborative systems from various economic fields. In order to evaluate a collaborative system, several metrics must be defined and analyzed from the point of view of following properties: sensitivity, not compensatory character, not catastrophic character, representativeness.

The real problem is to apply the metric and most important to validate it. The metrics of collaborative systems must be not too complicated, because will use lots of resources when implemented, and not too simple, because the measured levels will loose relevance.

Acknowledgements

This article is a result of the project POSDRU/6/1.5/S/11 „Doctoral Program and PhD Students in the education research and innovation triangle". This project is co funded by European Social Fund through The Sectorial Operational Programme for Human Resources Development 2007-2013, coordinated by The Bucharest Academy of Economic Studies, project no. 7832, Doctoral Program and PhD Students in the education research and innovation triangle, DOC-ECI.

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