

A Fuzzy Agent-based Approach to Trust-based Competency Management

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Abstract—In an era in which organizations increasingly consider the competencies of their employees as a crucial resource, human management becomes a key activity for improving staff and business performances. Important is also knowing who knows what inside the organization, so that project teams are assembled as the right mix of skill, knowledge and workforce abilities. At the same time, trust, an essential component, related to understanding interpersonal and group behavior, is an indisputable prerequisite for organizational effectiveness, in terms of social-cognitive capital, global competency as well as economic exchange and social and political stability.

This paper defines an approach to support competency-based management by providing recommendations about the reliability of a worker in terms of trust information and own competencies. The approach lies on an agent-based architecture which supervises the Human Resources Management (HRM). Task-oriented agents monitor the employees' profiles and capabilities by maintaining update the competencies and the trusts in the organizational social network. Particularly an agent endowed by fuzzy reasoning capabilities provides recommendation about workers' competencies in HRM decision-making processes.

Index Terms—Competency-Based Management, fuzzy rules, multi-agent systems, trust/distrust

I. INTRODUCTION

In a climate of global competitiveness, organizations can retain their competitive position by providing innovative products, services, and processes. The innovative potential of an organization depends on features such as skills, abilities, knowledge, experience, perspectives, and social network ties that it can draw on [1]. Organizations succeed in leveraging high levels of trust that represent a necessary condition that must be met for reaching the competitiveness potential. Trust has been defined as the “social glue” [2], that correlates positively with high degrees of personnel involvement, commitment, and organizational success. At the same time, it is “a mental state comprising expectancy (the trustor expects a specific behavior from the trustee) and belief” [3]. Computational trust models have recently been drawing the attention of many scientific communities from various disciplines [6], [7] to analyze interpersonal or inter-organizational trust in different domains such as e-commerce [8] and social web applications [9].

In literature [14], several works provide models for the trust management in virtual communities and social networks. Yet, they do not always consider the relationship existing between trust in competencies and the workers employed on specific jobs. A set of organizational processes identified by Competency-Based Management (CBM) guarantees that there is the right worker with the right competency in the right position at the right time in order to pursue high level of organizational productivity and effectiveness. Typically, CBM processes are top-down organizational processes supported by enterprise software that cannot be exploited to support team building operations in not-formal working activities.

It would be desirable to define an approach to enrich CBM with trust information in order to support the Human Resource Management in finding competencies. On the other hand, because trust is subjective measure of human beings, some works have exploited fuzzy logic as a possible best fit approach for manage uncertainties within organizational data. On the other hand, trust can be naturally expressed by linguistics terms rather than numerical values. In [8], trust has been modeled through Fuzzy Logic by defining a model for identify the information that customers expect to find on a vendors to increase their trust. The work described in [12] instead, exploits the theory of Fuzzy Cognitive Time Maps (FCTMs) into modeling and evaluating trust relationships in the virtual enterprises setting. Similarly to our approach, a fuzzy inference system has been exploited [13] to model trust measurement. The approach has been applied to improve knowledge sharing within a community to lead organizations to high level of productivity: the fuzzy system returns the degree of knowledge sharing. The goal of our approach instead is mainly devoted to suggest recommendations through the agents' supervision in HRM decision-making processes: our fuzzy system, embedded in an agent reasoning, suggests for each selected worker, the personal acquired level of competency.

Many researchers have studied the concept of trust in inter-organizational relationships and investigated trust between organizations [5], evidencing the important benefits produced by exploiting trust both individually and collectively. The

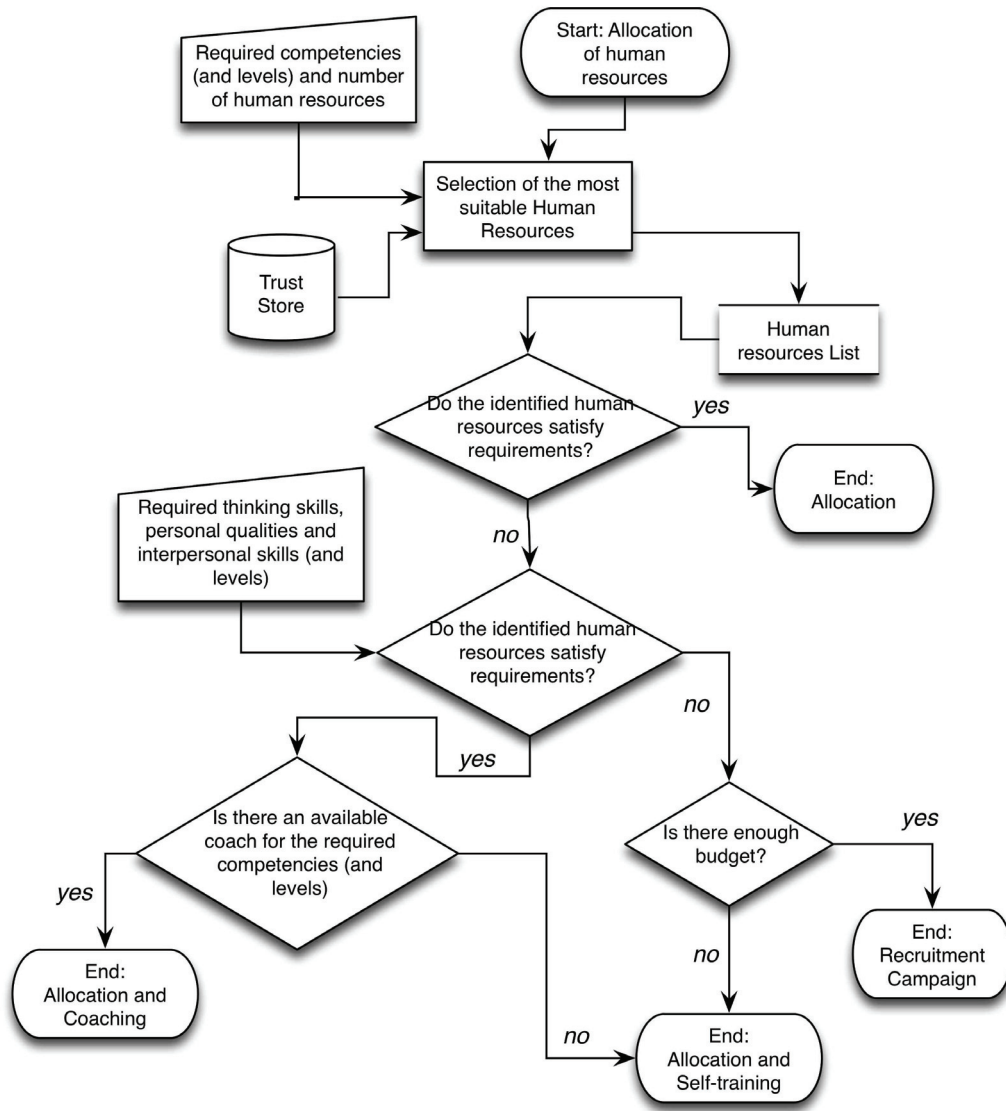


Fig. 1. Activities flow of an organizational strategy

influence of organizational procedures on attributions regarding organization' trustworthiness has been investigated in [5]. These procedures tend to increase trust between worker and supervisor or, in general, the trustworthiness in the organization. Trust might have positive effects on attitudes, perceptions, behaviors, and performance outcomes within organizational settings. In fact, the receipt of positive outcomes constitute evidence that the organization can be counted on to perform behaviors desired by the trustors and is related to employee job satisfaction and overall perceptions of organizational effectiveness.

This work presents an agent-based approach to support competency-based management in an organization. Recommendations address organizational strategies as well as the trustworthiness of a worker in terms of acquired trust degree and own competency levels. Fundamental role to reach this

goal is played by the team builder agent which embeds fuzzy reasoning capabilities, in order to provide recommendation about workers' competency in Human Resources Management (HRM) activities.

The remaining of this paper is organized as follows. Section II presents the main step of an enterprise strategy for the human resources management. The role of trust for the human resources allocation is presented in Section III where the concepts of trust and also distrust are formally given. Section IV depicts the logical view of the framework and the role of the agent-based platform. The tasks accomplished by each agent and their interactions are given too. Particularly, Section V provides a closer look on the task accomplished by the team builder agent; it implements a fuzzy inference system to deduce a single overall measure of the worker's competency. Then, Section VI gives an example of applicative scenario. Finally,

conclusion and future works close the paper.

II. ORGANIZATIONAL STRATEGIES

In order to refine the human resource allocation process we also need to consider the specific enterprise strategy with respect to human resource management. Figure 1 shows an example of an enterprise strategy aimed at allocating workers whose profiles meet the competency (and level) required by the Decision Support System (briefly, DSS).

In [11], a set of strategic human resource management practices are described. The most relevant, for the purpose of this work, are “Recruitment and Selection” and “Training and Development”. During a human resource allocation process, in situations where there is not a perfect match between the required competencies (and levels) and the available competencies (and levels), the awareness of the enterprise strategy could help the decision making. As shown in Figure 1, when there are no workers that match the required competencies and level, the strategy is designed to apply one of two practices. When the company’s strategies aim at growing its employees professionally, Training and Development is the favorite practice. It is selected if there are workers in the company that have the required competency, even though with a different (lower) level. In particular, additional skills (e.g. continuous learning, teamwork, etc.) and personal qualities are required for the human resources to be allocated. The strategy foresees a training time (individual or flanked by a coach if available) for them. Otherwise, if the organizational budget allows it, a recruitment campaign (Recruitment and Selection practice) can be activated. The flow of Figure 1 is only one of the plausible practices that an organization could use with respect to the current adopted strategies. A practice can be defined and executed by using a Decision Support System.

In the following sections an approach to refine and improve these practices, by using trust information, will be proposed.

III. TRUSTOR, TRUSTEES AND TRUST IN COMPETENCIES

Trust emphasizes how people work together and build effective relationships; it is a critical link to all good relationships, both personal and professional. When workers believe that they are working for trustworthy organization, they are willing to invest their time and talents in making a real contribution in the activities where they are involved. People who trust supervisor will invest more of themselves in their work. Similarly, the trustor evaluates the worker’s behavior on the activities, providing a trust degree which be rewarding and incentives him to do better. High trust degrees lead to a great sense of self responsibility, interpersonal insight and collective wishes to reach common goals.

In this work, the trustor is the corporate identified as the community of its employees, the trustees are the employees and we are interested in trust in competencies:

$$trust_c(e, x, k), \quad (1)$$

Category	Sub-category	Examples
Technical Competencies	Knowledge	Java language syntax
		Description logics
		UML notation
	Technical Skills	Java programming
		OWL modeling
		Project management
Behavioural and Cognitive Competencies	Thinking Skills	Problem-solving
		Innovation & creativity
		Continuous learning
	Interpersonal Skills	Teamwork
		Relationship management
		Communication
		Teaching others
	Action Skills	Decision-making
		Results orientations
		Planning & organization
	Personal Qualities	Integrity
		Self-motivation
		Responsibility
		Self-management

Fig. 2. Different types of competencies

The statement 1 indicates that the corporate (trustor) trusts employee e (trustee) regarding the capability of e to apply competency x in context k . Similarly, the distrust is defined as following:

$$distrust_c(e, x, k), \quad (2)$$

The statement 2 indicates that the corporate (trustor) does not trust employee e (trustee) regarding the capability of e to apply competency x in context k .

In the organizations, it seems to be a good choice to divide competencies into behavioral and technical competencies (see Figure 2). *Behavioral competencies* include all those soft skills and attitudes that enable a person to perform well in a specific function, such as *communication*, *problem-solving*, *integrity*, *planning and organization*, etc. *Technical competencies* are specific and depending on the job. These latter could range, for instance, from the knowledge of software development methodologies to skill for Java programming. Authors in [10] propose to calculate trust values in terms of frequencies of positive experiences between the trustor and the trustee. In our proposal, an experience is modeled as a work activity (or task). For each task there are a worker (an employee) and a supervisor. The underlying idea is that the supervisor assigns a rate to the performance of the employee involved in the task. The rate can be interpreted as a value indicating how the required competencies have been applied during the execution of the task. Our goal is to calculate the corporate trust in competencies for each employee. More in details, in the case of **trust in competencies**, formula (3) can be used. In this case the trustor is the corporate (intended as the community of

the employees) and the trustees are the employees.

$$\alpha = td_c(e, x, k) = n/m, \quad (3)$$

where m is the total number of situations in which e (trustee) has applied competency x in the context k , and n is the number of positive experiences in that set, β (distrust) can be calculated with the same formula (3) of α by replacing n with l and td_c with dtd_c , where l is the number of negative experiences in the same set. Values for n and l can be calculated with the following:

$$n = \sum_m^{i=1} e_p(i), l = \sum_m^{i=1} e_n(i), \quad (4)$$

where $e_p(i), e_n(i) \in [0, 1]$, representing the degree of the experience i being positive or negative separately, and $e_p(i) + e_n(i) \leq 1$. In the context of this work, a positive (negative) experience is represented by a task, that requires competency x , where any supervisor has provided a positive (negative) review rate $e_p(i)$ ($e_n(i)$) to the worker e for the application of competency x in the context k . Untrust γ can be calculated by using the formula $\alpha + \beta + \gamma = 1$ [10].

IV. ARCHITECTURE OVERVIEW

The proposed approach is based on an agent-based platform aimed at sustaining and exploiting trust-based competency management by improving decision making processes with respect to human resource management activities. The approach also foresees a mechanism to weigh up each decision with organizational strategies and policies. Figure 3 provides a sketched sample enterprise IT environment showing all the components/systems involved in our approach.

- **Human Resource Management (HRM) System** is a typical system used in enterprise context in order to manage employees' profiles, competencies, career plans, payroll, allocations, etc. Typically, HRM systems are not in charge of the trust management.
- **Competency Assessment System** represents a set of tools used to assess employees' competencies and relative competencies levels. These tools can range from questionnaires (electronic form-based, papery, etc.) to Web-based e-Testing System.
- **Collaborative Working Environment (CWE)** is a set of tools used, in the organization, to support employees' tasks. Document Management Systems, Collaborative Workspaces, Wiki, Blog, Instant Messaging and Videoconferencing are examples of these tools.
- **Decision Support System** represents an environment providing human resource managers with suggestions regarding decision making processes. In this work, we focus on decision making about human resource management.
- **Trust Store** is the database in which, for each employee, trust degrees are stored and associated to employees' competencies (and levels). Data used to calculate trust

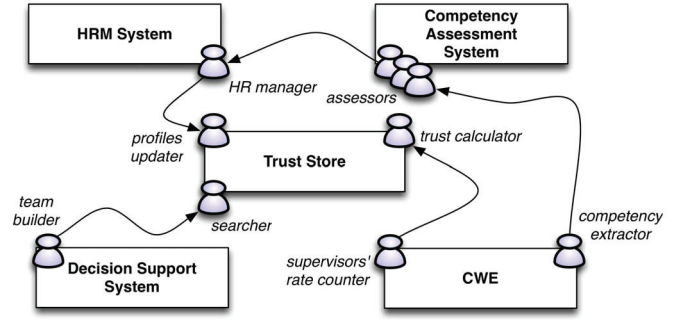


Fig. 3. Logical overview of the architecture

degrees for each employee are also maintained in Trust Store. We assume that for each employee there is a set of tuples $\langle \text{competency}, \text{competency level}, \text{context}, \text{trust}, \text{distrust}, \text{untrust} \rangle$ that states all the competencies owned by the employee. The first three values come from the Human Resource Management System. Trust, distrust and untrust values are calculated by agents exploiting a social approach. Competency is a label representing a specific competency (e.g. Project Management), competency level is a value in the set $\{\text{novice}, \text{advanced beginner}, \text{competent}, \text{proficient}, \text{expert}\}$ (according to Dreyfus model of skill acquisition [4]), context is a label (e.g. R&D Projects) representing the domain in which the competency is applied.

The agent-based paradigm represents the glue to make the several and heterogeneous systems communicating through distributed interactions. In fact, task-oriented agents are designed for each system to guarantee ACL-based communication, monitoring the interaction to each other and support a competency management in human resource processes such as, for instance, effective project team building. Let us introduce the role of each agent, associated to the components of the architecture.

- **HR manager agent:** handles workers' competency profiles inside the HRM system by updating them when new competencies must be added to a specific worker (this information comes from assessors agents) and by communicating last updates to the profiles and network updater agent.
- **Assessors agents:** handle different types (formal and informal) of workers' competency assessment. For instance, this agent is responsible for receive and elaborate the information extracted from collaborative sessions data and content in order to discover unknown competencies from actions and results of workers during their collaborative work activities carried out by using CWE.
- **Competency extractor agent** is responsible for extracting information about employees' competencies from content and data tracked by CWE and for communicating it to the assessor agent.
- **Supervisor's rate counter agent** is responsible for no-

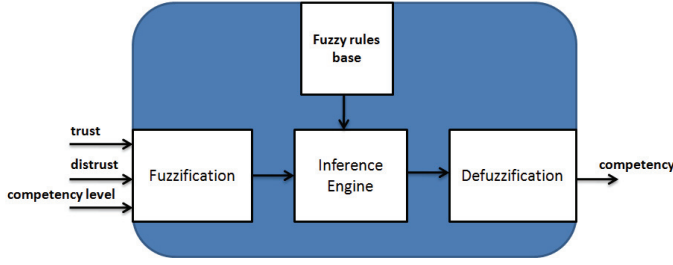


Fig. 4. Fuzzy Inference System

tifying new rates added by a supervisor to judge the performance (applying a specific competency) of a worker (trustee) with respect to a specific task. This agent communicates new posted rates to the trust calculator agent.

- **Trust calculator agent** uses supervisors' rates to produce trust degrees and updates values into the Trust Store.
- **Searcher agent** answers to the queries coming from decision support systems in order, for instance, to find workers owning specific competencies.
- **Team builder agent** provides recommendations about project team composition with respect to a set of needed competencies (and levels). This agent produces recommendations by elaborating information coming from the searcher agent.
- **Profiles updater agent** handles updates into the Trust Store with respect to employees' profiles (modifications to the owned competencies and levels) according to HR manager agent.

V. A CLOSER LOOK AT THE TEAM BUILDER AGENT

The aim of the team builder agent is to support DSS in the competency-based management and suggest recommendations for selecting suitable human resources to recommend to DSS. Precisely, this agent provides a list of workers whose competency matches the DSS request, in terms of competencies and associated levels. The goal of the agent is to provide not only the suitable workers that match the request, but, at the same time, evaluate the "accumulated" trust of the worker (during his previous organizational tasks) on the requested competency. In this way the agent suggests information which represents a kind of trade-off between the two different types of information: on one hand, the trust assigned (and calculated through the above described social approach) by the corporate to the worker on the requested competency, on the other hand, his competency and level in his profile. This balanced evaluation represents an added value that is not directly traceable by the DSS, but it is computed by agent exploiting its embedded reasoning model.

The team builder agent indeed incorporates a fuzzy inference system, which exploits a fuzzy rules base to deduct the overall evaluation of competency of a worker.

Fuzzy inference systems (FIS) are very simple conceptually (see Figure 4). They consist of an input stage, a processing stage, and an output stage. The input maps inputs to the appropriate membership functions and truth values (fuzzification). The processing stage invokes each appropriate fuzzy rule and generates a result for each, then combines the results of the rules (fuzzy reasoning). Finally, the output stage converts the combined result back into a specific control output value (defuzzification). The use of fuzzy inference system makes more intuitive the interpretation of values describing the trust (or the distrust) in a competency of the worker (i.e., trustee). In the real world, when human beings inquire to each other about the competency of an entity, preferably the answers are expressed through a linguistic terms, such as **HIGLY COMPETENT**, **NO COMPETENT**, etc., rather than using numerical values. In the light of this consideration, the team builder agent has been designed to simulate the human behavior, then it should provide answers using the same terminology as humans to make it more believable.

The fuzzy inference process exploits Mamdani's fuzzy inference method [15], which takes as input two numerical values representing the number of positive and negative experiences of some trustor for that worker (on a given context) and a competency level (assigned by the organization on the same context). Figure 4 shows information flows from three input variables to a single-output. Let us observe that the organization, by means HRM System, stores competencies (and levels) for each employee. Levels are defined according to the Dreyfus model of skill acquisition [4] which identifies five levels of competencies (detailed in Section IV). The competencies are assigned a priori to each workers through the organizational policy of competency Assessment System, through the assessors agents (see Figure 3), in accordance with their capabilities, certification and past working experiences. Competencies are always associated to a specific context in which they are applied, as said in Section IV.

The output of the fuzzy rules is a "synthetic" value that describes the overall competency of that worker for a specific context. Precisely, the IF-THEN fuzzy rules composing the knowledge based have the following form:

- IF trust is *high* AND distrust is *low* AND comp_level is *expert* THEN competence is *very high*
- IF trust is *high* AND distrust is *low* AND comp_level is *proficient* THEN competence is *high*
- IF trust is *medium* AND distrust is *low* AND comp_level is *proficient* THEN competence is *high*
- ...
- IF trust is *low* AND distrust is *low* AND comp_level is *advanced beginner* THEN competence is *low*
- IF trust is *low* AND distrust is *low* AND comp_level is *novice* THEN competence is *very low*

These rules evaluate a worker regarding to a specific competence by exploiting associated supervisors' trust and

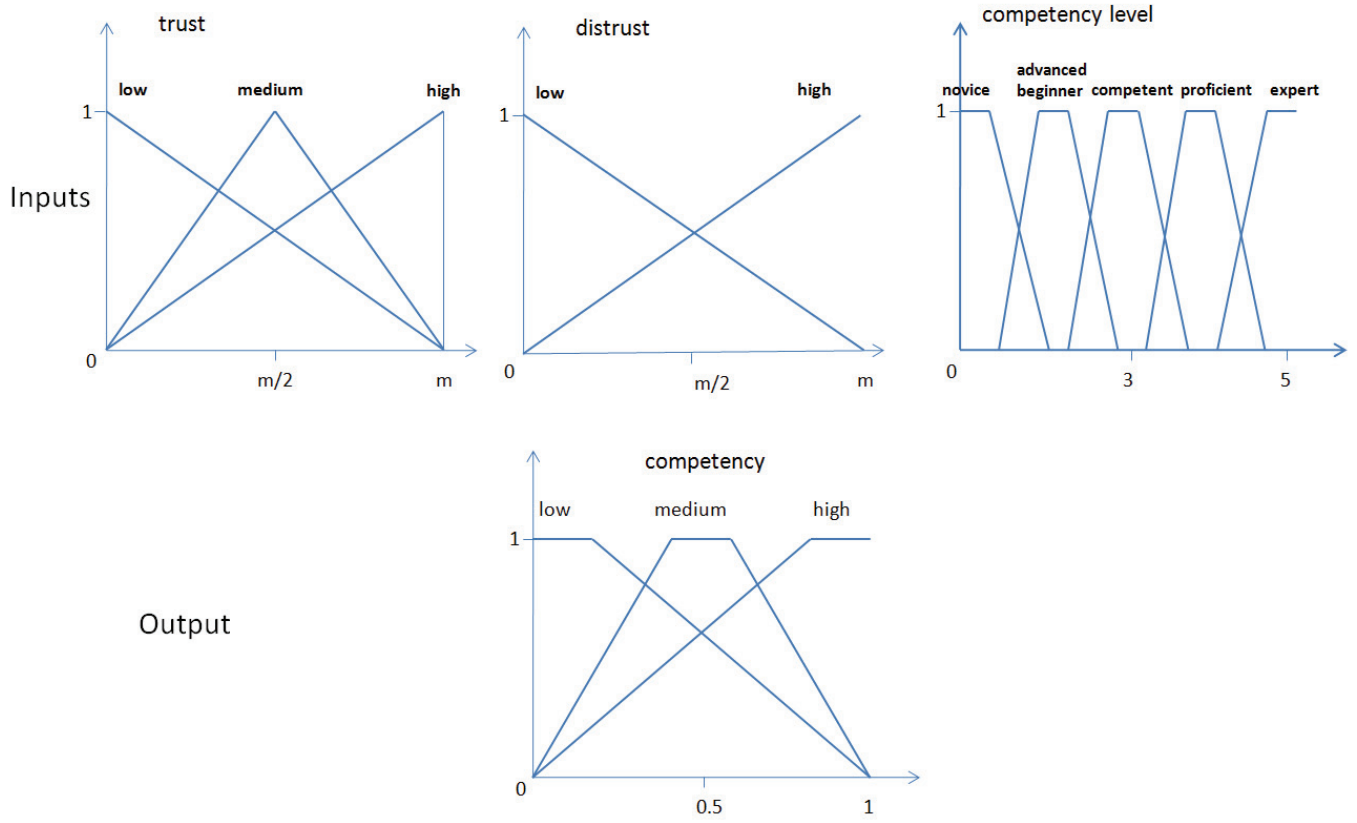


Fig. 5. Inputs and Output fuzzy sets for the reasoning of the team builder agent.

competence level.

Although the specific competency of each worker is related to the trust of the corporate, it is not influential in this stage, because we exploit only the type (positive or negative) of experiences gained during his working activities. Then, the untrust is not considered in this modeling. Figure 5 shows the fuzzy sets associated to the fuzzy reasoning embedded into the team builder agent. The linguistic terms of trust and distrust are modeled as triangular fuzzy sets, while the competence level is described by trapezoidal membership functions; similarly, the output is represented by trapezoidal membership functions. These functions seem good enough to capture the vagueness of those linguistic assessments. Due to many rules associated to knowledge base defined to model our variables, we give just same example of them. Moreover, the output fuzzy variable is defined through its primary terms: *low*, *medium* and *high*, the other are derived by applying linguistic modifiers (not shown in Figure 5).

Note the function memberships describing the inputs have the same distribution for all the worker, even though the input fuzzy sets are defined on a domain which depends on a parameter m . The value m represents the total number of situations in which the trustee has exploited his own competency in a certain context, according to the definition of *trust in competencies* (see formula (3)). This value strictly depends on the worker. Specifically, for each worker, the team builder agent loads the

relative fuzzy rules based knowledge and applies the inference based on the instanced set of fuzzy rules.

According to the Mamdani-type inference, the output of the fuzzy system is a single value computed by defuzzification of the aggregated output fuzzy sets. Herein, we have exploited the most popular defuzzification method, i.e. the centroid calculation, which returns the center of area under the curve representing the aggregated output. This value represent the “overall” competency of a given worker in a given context.

For each selected worker, the team builder agent returns a synthetic competency value. Then a ranked list of workers is returned. It represents the recommendation to send DSS.

VI. AN EXAMPLE SCENARIO

Let us suppose a team building request occurs. The DSS requires for some specific competencies with the associated level of assessment about those competencies in some specified context. For instance, one of the desired requirements might be to select a human resource whose competence level is *expert* in Java programming and *proficient* in team working. The searcher agent, which is in charge of complying this request, returns to the team builder agent the set of workers that have both the competencies. For each worker, the agent instantiates the set of fuzzy rules associated to him: his value m of total number of situations (experienced by trustors) and the fuzzy set representing the own competence level as well. In

other words, if the worker d has competence level *competent* in Java programming and his number of experiences in this context is 7, the relative fuzzy rules base will be the domain $[0, \dots, 7]$ of membership functions for trust and distrust (see Figure 5) and the linguistic term used will be *competent*. Thus, the team builder agent applies the inference model on the knowledge based associated to that worker and deduces how he is “competent” in the specific context. At the end, the ranked list of all the workers is returned.

It is interesting to observe that sometimes an organization prefers to select workers with competencies levels that are slightly lower than the desired ones, for internal policy such as personnel cost, career development, etc. As said in Section II, Figure 1, the organizational strategies/policies could be to apply “Training and Development” practice. In fact, it would be desirable that, when the team builder agent is committed to find human resources with a specific competency level (in a given context), it does not answer with a perfect match, but provides workers whose competency level and trustworthiness together approximate the request.

The agents should select all the workers that have competency in a requested context (for instance, in Java programming), without further filtering on the required competence level. An idea is to use for each worker twice the fuzzy inference system: firstly, compute the overall competency by exploiting his competence level, as described in Section V. We call the final value of inference process the *personal competence* of each worker. Then we would evaluate the expected overall competency of the selected worker, considering instead the required its competence level. The goal is to compare the two output values. Thus, when the team builder agent instantiates the fuzzy inference rules associated to a worker, executes once the inference with its personal rule base. Then it executes a modified version of the worker rules base that substitutes the fuzzy linguistic term describing the competence level of worker with the required one.

After the inference, the agent obtains two values that represent the competency: the *personal* and the *expected* ones. By comparing the two values, it is possible to assess how much the personal value of worker’s competence approximate the expected one. Thus, the agent will return the worker whose difference between these two values is minimum. Let us note that when the agent selects a worker whose competence level fully matches the requested one, the two values will be equal. This comparison allows us to get the worker whose competence approximates to desired one. More important, the output values include an evaluation with respect to the trust. In other words, we evaluate the competence of a worker (with respect to the requested one), taking into account also the trustworthiness of the worker. The final ranked list will be a pool of suitable human resources, which could do not fully match the DSS request, but meets the organizational policy.

Modelling the competence level, trust and distrust allows us to get a new measure of competence as a balanced mix of these parameters that could better reflect the organization policy. This result is preferable to a crisp reply for the request “all and

just the workers with a given competence level on a context”, that can mean an high cost in terms of resources allocation. As said in Section II, the organization can be interested in activity of “Training and Development”, to professionally increase the competencies levels of its employees. The fuzzy inference model of the team builder agent can provide this kind of answers.

VII. CONCLUSION

This paper defines an agent based framework which supports competency-based management. The trustworthiness of a worker is evaluated as combination of his accumulated trust and competency levels for a specific context. A fuzzy inference system, embedded into the team builder agent, accomplishes the combined evaluation which provides an added value to the overall evaluation of a worker, through an adequate balancing of human expertise, competencies and capabilities. The agent returns recommendations to DSS request, providing a ranked list of the workers which matches or just approximates the request competency and level.

In this work, we have exploited Fuzzy Logic to model the trust (and distrust) in competency as well as the competency level. Although the modeling of this framework is still in progress, as future work, we intend to extend the fuzzy modelling to other parameters related to organizational strategies and the human resource management. The approach will be experimented in ARISTOTELE FP7 EU-Project.

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