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Abstract: This paper presents a summary of relevant research findings that have been used as the theoretical background in the design of an agent-based model to simulate the human behaviour within work teams (the TEAKS model). It underlines some of the main trends in the modelling of human behaviour in teams, and the rationale for selecting the attributes to represent real team candidates as software agents in the TEAKS model.

1 Introduction

Computer simulations to analyse and understand complex phenomena have been applied in several research disciplines including Automation [1], Economics [2], Social Sciences [3] and Environmental Sciences [4]. The success in the use of simulations within these research areas relies on the feasibility to *play* with the behaviour of the modelled phenomenon under study by changing the conditions of its environment and its internal parameters to observe the consequences in a controlled experiment.

The study of human behaviour under specific contexts and circumstances has been one of these complex phenomena under study since early 70's [5]. Over the past few decades, tools and techniques for modelling and predicting human performance in complex systems have evolved and matured, for instance, considering task network models [6] and situational awareness models [7], among others.

In the last years, agent-based modelling has emerged as a relative new technique to model social behaviour, particularly helpful for the modelling of individuals immerse in a social environment such as groups, organisations or societies. The key characteristic of agent-based models is the concept of *Agent*, which is an autonomous software entity with the ability to interact with other agents and with the environment. Autonomy means that agents are active entities that can take their own decisions. This is not the same with objects, as they are predetermined to perform the operations that someone else requests them. An agent, however, will decide whether to perform or not a requested operation, taking into account its goals and priorities, as well as the context it knows. In this sense, the agent paradigm assimilates quite well the individual in a social system.

This paper presents a summary of relevant research findings that have been used as the theoretical background in the design of an agent-based model to simulate the human behaviour within work teams, which has been implemented as the TEAKS model [8]. It first underlines some of the main current trends in the modelling of human behaviour in teams. Then, it focus on explaining the rationale behind the selection of the human attributes that have been included in the TEAKS model to represent real team candidates as software agents.

2 Modelling Human Behaviour in Work Teams

The modelling of human behaviour is a great challenge due to the instability, unpredictability and the ability to perform independent actions of human nature. Nevertheless, in the recent years several models and techniques have emerged that clearly indicate that some contextual-limited modelling of human-like behaviours are possible such as in training and learning [8], and for the representation of crisis and emergency situations [9], among others.

An interesting scenario where models of human behaviour are applied is for the analysis and understanding of the different dynamics that take place within groups and teams under specific context. Some examples of works where group behaviours are analysed using agent-based models include the presented in [10], which analyses the behaviour of a group of agents facing the management of common pool resources. Also, [11] report the analysis of the performance in military combatants, studying the effect on their behaviour of individual and social factors. The analysis of a group's behaviour and dynamics when facing the adoption of a new software application is other application described in [12].

One type of teams particularly interesting is the one formed by people in front of their daily activities at work to perform a set of tasks. The analysis of the behaviour and performance of these work teams can support the decision making process of managers to select the right persons to form better work teams taking into account the fact that a group of people with optimal individual abilities may perform sub-optimally acting as a work team [13]. From a research point of view, this scenario offers several dimensions to be studied given that the work team's performance is influenced not only by the personal expertise and responsibilities of each team member, but also by some personal characteristics that influence individual, and in consequence, team performance [14].

In this context we have developed TEAKS (TEAm Knowledge-based Structuring), an agent-based model where a virtual team can be configured using the characteristics of the real candidates to form a team of software agents, and given a set of tasks, the model generates statistical information about the possible performance of the agents obtained from the interaction between all the team members and with their assigned tasks [8].

The representation of the real candidates through software agents required a careful study about the individual (internal) attributes to model in the software agents. It is difficult to include all the internal human attributes that affect, influence and direct the behaviour of a person. The most common strategy to follow is to select only those attributes that are important in the context of the phenomenon that will be

studied. In this sense, the next section presents a brief review of existent research that indicates the importance of some specific internal attributes in human behaviour, in the context of human behaviour at work and within work teams. Additionally, a brief review of some existent artificial systems and architectures that implement the identified attributes are mentioned.

3 Individual Attributes in the Modelling of Human Behaviour

A key set of human attributes that influence and direct behaviour within work teams were identified and included in the TEAKS model. Four human attributes were selected and implemented in the model: *creativity*, *emotions*, *personality traits* and *trust.*

3.1 Creativity

The research discipline that traditionally has focused on the study of human behaviour is the Psychology. The psychological cognitive approach focuses on how humans think with the belief that such thought processes affect the way in which humans behave. The interest and development of this psychological approach has been increased from the 1960s originating the Cognitive Science.

According to [15], the central hypothesis of cognitive science is that thinking can best be understood in terms of representational structures in the mind and computational procedures that operate on those structures, i.e. the Computational-Representational Understanding of Mind. The mental processes that are studied in cognitive science include *comprehension*, *inference*, *decision-making*, *planning* and *learning*. All these mental processes produce at the end an intelligent human behaviour with the capabilities to develop highly routine tasks to extremely difficult, open-ended problems.

In the context of human behaviour at work, several studies along the years have proved the high influence of the cognitive abilities on work performance across different types of jobs [16]. One particular outcome originated from the different mental processes that has been deeply studied in the analysis of work performance is the *creative behaviour* [17]. Research has linked five specific cognitive abilities that influence creativity: *problem framing*, *divergent thinking*, *mental transformations*, *practice with alternative solutions*, and *evaluative ability*. The concept of creativity has received much attention (mainly in the Organisational Psychology and Human Resources disciplines) due that it is considered the basic ingredient to be innovative [18], which in turn is a key factor to increase the success in the work performance of an individual, group or organisation.

Moreover, the cognitive and creativity research topics have not remained to exclusively understand work behaviour and/or performance at individual level, but both have been extended to cover the understanding and improvement of behaviour in work teams. In concrete, the term *team cognition* has been linked to effective team performance and it includes knowledge about team members, task-specific information, and team processes [19]. Team cognition has been also attracted the

attention of researchers on creativity to analyse and better understand the creative processes and outcomes that take place at group/team level [20].

3.2 Emotional Behaviour

In the past, for many years the main belief was that emotions are an undesirable product of the human rational mind, and thus the less emotional a person was, the more intelligent and reasonable the person was. Nevertheless, in recent years some researchers have proved that emotions are a relevant part of the human reasoning and necessary for an intelligent behaviour [21].

In the context of human behaviour at work, the influence of emotions is also recognised of great importance. The clearest example of this importance is the development of the relatively new concept of Emotional Intelligence. According to [22], Emotional Intelligence is composed of four abilities: *(1)* the ability to identify one's own and others' emotions to accurately express own emotions to others; *(2)* understanding how emotions orient people toward important information and how different emotional states can induce varying approaches to problem solving; *(3)* understanding the meaning, progressions, and complexity among emotions; and *(4)* the ability to stay open to feelings, to detach, and to manage one's own and others' emotions promoting emotional and intellectual growth.

With regard to the influence of emotions within work teams performance, despite the fact that group researchers have long acknowledged the importance of group's emotional life in its performance, there is relatively little research to date. Most of the studies have focused on individual level issues to show a positive relationship between emotional expression and organisational commitment [23]; a positive relationship between emotions and work motivation [24] and the different types of emotions that can be experienced at work [25]. Some others have concentrated efforts on evaluate the effects of mood (different than emotions) into work team performance [26]; and only few studies have reported how emotions influence directly (e.g. *envy* in work teams [27]) or indirectly (e.g. analysing the role of emotions in conflict management within work teams [28]) the work team performance.

From the existent psychological theories of emotions, the cognitive appraisal theories focus on the elicitation of emotional experiences as result from constant evaluations of the subjective significance of construed situations and events, according to specific dimensions or criteria [29]. The key characteristic of these theories is that the emotional process is seen as the permanent assessment of the environment according to the person's goals, intentions and standards, i.e. *appraisal*. Due that cognitive appraisal theories are focused on emotion as a process rather than in the descriptive characterisations of emotions in dimensional or categorical models, several works in modelling human behaviour are based on these theories. One of the most influential theories for implementation in artificial systems has been the often referred as the OCC model [30]. In summary, the OCC model relates types of emotional reactions to types of emotional responses. An individual can have positive or negative reactions to a specific situation depending on how the object of the appraisal (an event, and action of somebody or an actual object) is relevant to the individual's goals, to the standards it tries to uphold, or to its tastes. The OCC model

is used as the theoretical basis in several applications, and more deeply referred to model an intelligent and believable behaviour in synthetic characters [31].

The above mentioned theories, studies, and implementation works are only small evidence about the increasing interest in the study and modelling of emotions, a deeper analysis can be found in [32]. It is clear the high importance that the emotional behaviour has on the global human behaviour and the modelling of it in artificial systems has originated great efforts such as the development of new research branches (e.g. Affective Computing [33]) and large research associations (e.g. HUMAINE: http://emotion-research.net/).

3.3 Personality Traits

Another branch of the Psychology that has dedicated efforts, since long time ago, to the study of human behaviour based on the identification and classification of individual differences is Personality Psychology [34]. Due to the development of different theories of personality, there is not an achieved consensus about the definition of the concept, but the different definitions of personality have some common features. In [34], three main features are proposed: *i) uniqueness of the individual*: each person is different; *ii) uniformity of behaviour:* behaviour of the individual is consistent over time and across situations; *iv) Content and processes*: personality consists of something that influences behaviour, e.g. how our expectations in one situation influence our behaviour in others?

The different theories of personality have originated also different models containing various dimensions to assess the distinct (but consistent) styles of behaviour. In 1923 Carl Jung [35] proposed two types of attitudes in people: *extraversion* and *introversion* which modify four Jung's proposed functions of consciousness: perceiving (Sensation and Intuition) and judging (Thinking and Feeling). Other model of personality was proposed by Hans Eysenck [36] based on the biological perspective of personality. The Eysenck's model, known as the P-E-N model, initially includes two dimensions of personality: *extraversion* and *neuroticism*, adding afterwards the third *psychoticism* dimension.

Probably the most accepted (but not exempt of criticism) personality model is the known as the Big Five model [37]. The five big factors of personality, also known as the OCEAN model, include *Openness*, *Conscientiousness*, *Extroversion*, *Agreeableness* and *Neuroticism*.

In the context of human behaviour at work, one of the studies that have focused on the identification of the personal styles that affect the job performance and relationships is the presented in [38], where four styles of behaviour were found represented in any occupation. The four proposed patterns of behaviour at work are *Amiable*: the Relationship specialist; *Analytical*: the Technical specialist; *Driver*: the Command specialist; and *Expressive*: the Social specialist.

Regarding the influence of the personality traits within work teams, several studies have been developed to relate the different traits of personality with the team performance. A study developed with an engineering team found that team members who possess high level of conscientiousness manifested increased task performance, while those with minimum composite level of extraversion are highly successful in managing product design processes [39]. More recently, a different study was

developed using 78 college students working in 10 long-standing teams competing in a business simulation, finding that emotional stability (the opposite trait of *neuroticism*) predicted task performance and agreeableness predicted cohesion within the work team [40].

It can be argued that the results obtained from the different studies largely depend on the types of activities of each work team, but it is unquestionable that the personality traits are another important factor that directs the behaviour of a person. Due to this fact, the interest to include models of personality into artificial systems has been increased in the last years (just as same as the emotions) to reproduce more realistic human behaviours. In the development of synthetic characters (more commonly known as virtual characters) different theories of personality psychology are applied to direct the behaviour of these artificial entities. Virtual characters with personality have been used for pedagogical purposes [41], the simulation of bargaining in e-commerce [42] and entertainment [43] among some others.

3.4 Trust

Additional relevant factors that directly affect human behaviour are the actions and behaviours of the other people whom the individual is interacting in its same environment. This is especially important when talking about work teams due to the importance that human relations have to achieve team-working behaviours (such as good communication and co-ordination among the team members) and are the foundation of *healthy and productive work environments* [44].

An important factor that contributes to create and maintain the productive work environments is the concept of *trust.* The increasing interest in trust within organisations could be explained as there are more and more large companies and consortiums where several people need to work together from different geographically locations. New theories and hypotheses about the thinking and functioning of organisations have been replacing traditional aspects of management by collaborative approaches emphasising ideas of coordination, sharing of responsibilities and risk taking [45]. More recently, and with the great development of applications in Internet, the interest in the study of trust has grown up and some research works put efforts towards the modelling of trust and reputation concepts addressed mainly to e-Commerce applications. Most of these models of trust and reputation use software agents as the entities where the relationship of trust takes place and is represented using specific characteristics of each model [46]. Some other models and studies have been developed in the Human Resources and Management disciplines to analyse the importance of trust within work teams and how it is related with performance effectiveness [47].

4 Conclusions

All the studies presented in this paper show the relevance of different individual attributes in the generation of human behaviour. Even that the selected set of attributes is not, of course, the complete spectrum that produces, influences and directs the

human behaviour, it is at least, an important part of the complete picture and allows the study and understanding of work team dynamics.

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