Computación y Sistemas. Vol. 7 No. 3 pp. 210 - 223

Agent Based Simulation in the Selection of Work Teams

Simulación Basada en Agentes en la Selección de Equipos de Trabajo

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Abstract:

When a new project starts in Industry, the correct selection of people to integrate a work team in order to develop that project is not trivial. The success of a project is greatly due to the personal responsibility of each member, but also to an adequate communication, collaboration and co-operation between the individual team members. In addition we consider that emotions play a critical role in rational decision-making, perception, human interaction, and human intelligence. Nowadays, the team selection process is typically done by one person (a manager) based on his/her past experience and his/her own information about the people's competence and availability. We present an Agent based model to simulate the human behaviour in a work team and a first prototype that implement it. Some initial results are discussed and the future work is presented.
Keywords: Emotions Modelling, Social Simulation, Multi-Agent Systems, Human Performance Modelling.

Resumen:

En la industria, cuando un proyecto nuevo es aprobado, la correcta selección de las personas que integrarán el equipo de trabajo que resolverá este nuevo proyecto no es una tarea trivial. El éxito de un proyecto se debe enormemente a la responsabilidad personal de cada miembro, así como a una adecuada comunicación, colaboración y cooperación entre cada uno de los integrantes. Actualmente el proceso de integración de equipos de trabajo es realizado típicamente por una o un conjunto pequeño de personas (director(es) de proyecto) basándose únicamente en su experiencia y en la información sobre las habilidades técnicas de la gente disponible. En este trabajo presentamos un modelo basado en agentes para simular el comportamiento humano en un equipo de trabajo. De igual manera, en este trabajo hemos considerado la importancia de los estados emocionales y rasgos de personalidad en la interacción e inteligencia humana. Se presenta también un prototipo que implementa el modelo propuesto. Se describen también algunos resultados iniciales y finalmente se presenta el trabajo futuro.
Palabras Clave: Simulación Social, Sistemas Multi-Agentes.

1. Introduction

In industry, the correct selection of people to integrate a team within a complex engineering project is not trivial because it should include not only technical competence and availability aspects, but also personal and social characteristics of each potential team member.

The success of a project is greatly due to the personal responsibility of each member, but also to an adequate communication, collaboration and co-operation between the individual team members [1]. Often, a good working environment depends on the personal characteristics of each worker. This is even more important in a project, where the interaction and communication between team members are fundamental for the achievement of the final objective. In addition to social and external factors, emotions play a critical role in rational decision-making, perception, human interaction, and human intelligence [2]. The particular emotional state of a person is an additional factor that affects the performance of his/her work and the work of the whole team. The emotional state of a person varies with time; furthermore, given the same circumstances, the reactions of different people can be quite different.

Since one of the goals of Artificial Intelligence is to design and implement systems that simulate human intelligent behaviour [3], we propose that some of its techniques can be very useful to support the configuration of work teams. More specifically, we think that the Multi-Agent Systems (MAS) could help to simulate human behaviour within a team given its capability to account characteristics such as autonomy, co-ordination and communication [4].

This paper presents our research work proposal in order to help in solving the problem for the configuration of work teams. We have proposed an agent based model to simulate each team member with a software agent that includes not only technical competence and availability aspects, but also some personal and social characteristics [5].

In section 2 we present the components of our model. Section 3 presents the description of the system that implements our model and Section 4 shows the preliminary results. Finally, in the last section the conclusions and future work are described.

2. Proposal Model

In our model, when a project is started, the project manager selects, according to his/her own experience, a possible set of team members. Once the team is formed, several simulations of its behaviour are performed. If the overall results indicate that the team could possibly complete the project with success, the project manager has the possibility to save the team configuration in a file for future reference. However, if the simulations do not predict an acceptable performance, the project manager has the possibility of adding, removing or modifying the team members, until a suitable team is identified (figure 2.1).

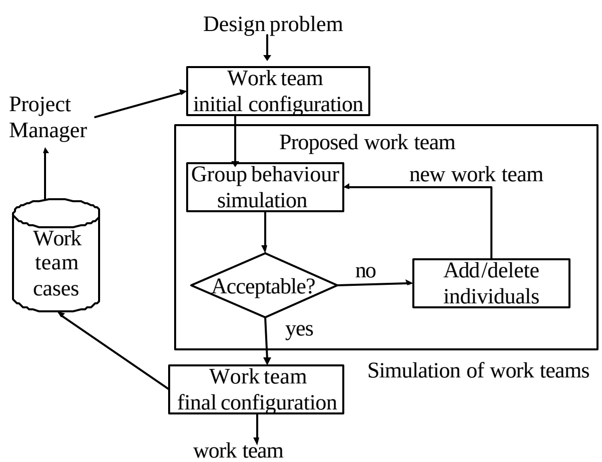

Fig. 2.1. Team Selection Process.

We use software agents to represent each person from real life. The internal model of our agents is based on the PECS architecture [6] where the physical component has been removed (at the moment, we do not need to simulate physical characteristics in our agents) and personality traits have been added to the emotion component.

The agents have a specific role within the team, this role is given by the type of tasks that the agents should achieve. To assign roles, we use as a case study a team in charge of a conceptual design problem [7] due to the large number of people with diverse backgrounds involved in the process [8]. The roles that we have considered are the following:

- **Project Manager**. The agent with this role simulates to have the knowledge of the person in charge of the team, and also specialised task knowledge.
- **Engineer.** These agents simulate to have knowledge about specialised tasks of the project. For example Chemical Engineers, Environmental Engineers, etc.
- **Technician**. The technician simulates having knowledge about specific technical tasks, e.g. simulation packages, statistics, etc.
- **Assistant**. Agents that simulate the work of people who are involved in routine, repetitive tasks, e.g. data acquisition, graphics, etc.

The internal characteristics of a software agent are then matched with the ones of a real person using the three basic aspects which represent the second layer of the PECS architecture:

- **Cognition** to represent some technical related knowledge of a person, i.e. creativity and experience.
- **Emotion** and **personality** to represent some emotional states. We consider the following basic emotions: *desire* [9], *interest* and *disgust* [10], and *anxiety* [11]; we also consider the *stress* parameter. Personality traits: *amiable*, *expressive*, *analytical* and *driver* [1] (Table 2.1).

Amiable
Emphasis: Steadiness; co-operating with others to carry out the tasks. **Pace:** Slow and easy; relaxed. **Priority:** Relationships. **Focus:** Getting acquainted and building trust. **Irritation:** Pushy, aggressive behaviour. **Speciality:** Support; "We're all in this together so let's work as a team".
Expressive
Emphasis: Influencing others; forming alliances to accomplish results. **Pace:** Fast. **Priority:** Relationships. **Focus:** Interaction; dynamics of relationships. **Irritation:** Boring tasks and being alone. **Speciality:** Socialising; "Let me tell what happened to me...".
Analytical
Emphasis: Compliance; working with existing circumstances to promote quality in products and services. **Pace:** Slow; steady; methodical. **Priority:** The task **Focus:** The details; the process. **Irritation:** Surprise; unpredictability. **Speciality:** Processes; systems; "Can you provide documentation for your claims?"
Driver
Emphasis: Dominance; shaping the environment by overcoming opposition to accomplish the tasks. **Pace:** Fast. **Priority:** The task. **Focus:** Results. **Irritation:** Wasting time: 'touchy feel' behaviour that blocks action. **Speciality:** Being in control; "I want it done right and I want it done now."

Table 2.1. Different personality types. (Material from S. Schubert, Leadership Connections Inc., Highland Lake, NJ 07422)

- **Social characteristics** to represent the interaction between team members: *introverted/extroverted*, *preferring to work alone* or *preferring to work in a team*.

2.1. Tasks Representation

In our model, the agents do not solve a real conceptual design problem but only simulate their interaction with other agents and with their assigned task(s). The representation of these tasks includes the following parameters:

- **Number of participants.** Number of agents required to perform that task.
- **Duration of the task.** Every task must have a duration from its starting point to the end. This time is measured in working days.
- **Sequence of the task.** The form in which the tasks are executed is important, there are tasks that should start when another task(s) have finished. Other tasks are completely independent and can be executed in parallel.
- **Difficulty of the task.** A task can be complex or not.
- **Type of task.** Generic or specialised task.
- **Deadline.** Some important tasks may have a deadline. Some tasks can be delivered before or after an estimated due date, but there are crucial tasks that must not exceed the deadline. If a task with a deadline is running late, a re-organisation within the team should be considered to complete the crucial task.
- **Priority of the task.** Every task has a priority parameter, and the agents must be capable of reorganise their work to complete on time the tasks with the highest priority;
- **Quality of the task.** This parameter represents the task quality generated by the agents in charge of that task and is consequence of the agent's behaviour.

The value of some of these task parameters changes when the agent interacts with the task, and by the same token, some internal parameters of the agent (e.g. anxiety, stress, interest, etc.) are altered by the parameters of the tasks such as priority, quality and deadline.

The division of the project into tasks and the sequence and the type of these tasks is an input to the system, therefore our application does not verify whether the planning of the project is correct or not.

2.2. Generation of the Agent Behaviour

The agent behaviour is given by the interaction between its internal state with its assigned task and with the internal state of its team-mates. One feature that we have introduced in our model are random variations around each internal parameter value of the agent to account for the non-deterministic nature of human behaviour. These random values generate different results for each simulation even if the same team is working on the same project. We generate these random probabilities using a normal distribution curve (see Figure 2.2).

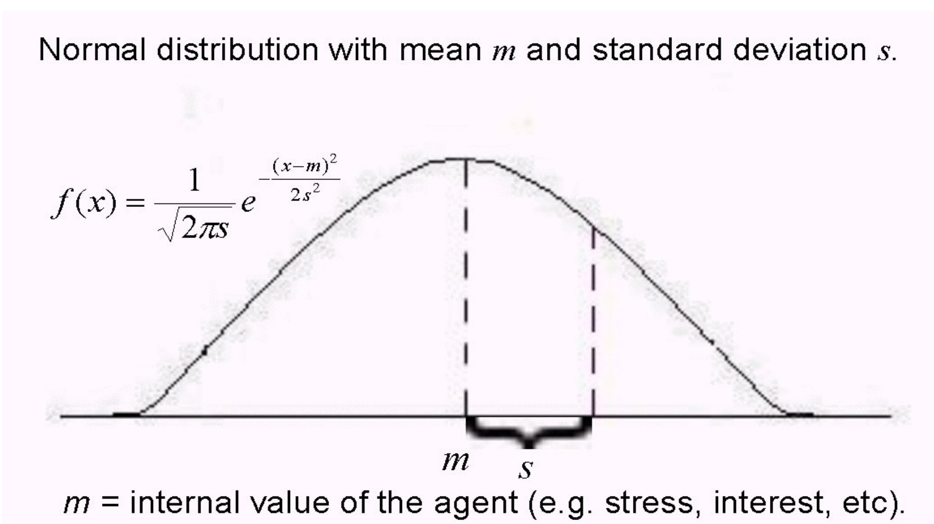

Fig. 2.2. Normal distribution curve to generate random values around each agent's internal parameters.

All the internal values of the agents are measured using fuzzy logic. For example, Agent A may have the following values in its *cognition* component:

Agent_A(*creativity, high),*
Agent_A(*experience, medium),*

and in its *emotion* component:

Agent_A(*desire, medium*),
Agent_A(*interest, high*),
...

These values could change according to the task assigned. With these internal parameters each agent simulates the interaction with other agents and with their assigned task(s).

From this interaction, two of the tasks parameters are modified: *task duration* and *task quality*. These two parameters are also quantified using fuzzy logic. As a result of the interaction between Agent A and the Task X, the duration and quality task parameters change using fuzzy values as follows:

Task_X(*duration, high_advance*),
Task_X(*quality, decrease_medium*).

Once the quality of the task is determined from the interaction between the agent with its task, the internal state of the agent is modified again as consequence of this generated value. This process is repeated with all the agents and their assigned tasks until the simulation of the whole project is made (see Figure 2.3).

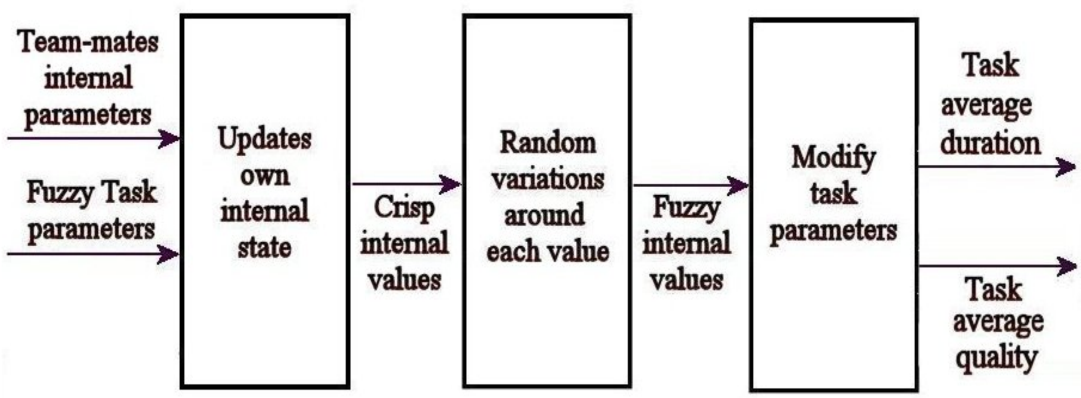

Fig. 2.3. Agent behaviour generation process.

The whole algorithm that produces the agent's behaviour is as follows:

1. The agent identifies its assigned task and its team-mates in that task.

2. According with the parameters of the task and the internal parameters of the other agents, the agent internal state is updated using fuzzy rules. For example given the Agent_A in charge of Task_X:

   IF Task_X(*is_delayed, high*)
   AND Task_X(*quality, low*)
   AND Task_X(*difficult, complex*)
   AND ....
   AND Agent_A(*experience, low*)
   AND Agent_A(*creativity, medium*)
   AND Agent_A(*personality, driver*)
   AND ...
   THEN
   Agent_A(*interest, decrease_medium*)
   AND Agent_A(*anxiety, increase_high*)

AND ...

3. Once the agent internal state is updated, each agent simulates to perform its assigned task. The task outputs parameters are updated. For example:

   IF Agent_A(*interest, medium*)
   AND Agent_A(*disgust, low*)
   AND Agent_A(*creativity, medium*)
   AND Agent_A(*prefers to work alone, works with others*)
   AND ...
   THEN
   Task_X(*duration, medium_delay*)
   AND Task_X (*quality, increase_high*)

4. If Task_X precedes Task_Y, then the defuzzified value of Task_X *duration* parameter is added to Task_Y *duration* crisp parameter. Finally the agent in charge of Task_Y updates its internal state according with the Task_Y parameters (step 2).

For all the fuzzy values we use the Gaussian-shaped membership function. For the matching rule we use the Mamdani fuzzy rule-based model [12] (the minimum operator) to represent the "AND" in the premise and the implication. To obtain crisp values (i.e. the defuzzified values) we use the *centre of gravity* (COG) method given by the formula:

$$u^{crisp} = \frac{\sum_i b_i \int \mu_{(i)}}{\sum_i \int \mu_{(i)}}$$

where u^{crisp} is the defuzzified value; b_i denotes the centre of the membership function of the consequent rule and the integral of $\mu_{(i)}$ denotes the area under the membership function $\mu_{(i)}$.

Finally, the fuzzy sets for the *creativity* and *experience* parameters are also measured like the intensity of basic emotions, with a Gaussian-shaped membership function and the following fuzzy values: *low experience / creativity, medium experience / creativity* and *high experience / creativity*. The difference of these two internal parameters is that they are not modified through the simulation of the project.

3. Implementation of the Model

The implementation of the model is described in this section. This prototype is being implemented using the Java Agent DEvelopment Framework (JADE) for MAS development (see http://jade.cselt.it). We choose this framework because it is FIPA (The Foundation for Intelligent Physical Agents) compliant (see www.fipa.org).

For the "reasoning" of the agents over its environment (its assigned tasks and its team-mates) we use the java rule engine call it JESS (see http://herzberg.ca.sandia.gov/jess/) and FuzzyJESS for the implementation of the internal fuzzy values and fuzzy rules of the agents (see http://www.iit.nrc.ca/IR_public/fuzzy/fuzzyJToolkit2.html).

Our first prototype has the following assump tions and limitations:

a) The agents do not solve a real conceptual design problem but only simulate their interaction with other agents and with their assigned task(s);

b) Given the uncertainty associated with the characterisation of the cognition, emotion, personality and social properties of a person, random probabilities around the fixed values of such properties (representing the internal state of the agent) will be used.

c) The set of global behaviours of a team is obtained by averaging its behaviour over a statistically significant number of simulations.

d) The most suitable team configuration can be obtained by comparing the sets of global behaviours for several possible team configurations.

3.1. Components of the System

Our prototype has the following three main components:

Configuration module. In this component the user must configure the initial team. Two or more agents form the team, and the user must also configure the internal state of each agent. Once the team is configured, the user must specify the project that the team will perform, i.e. the characteristics of the project tasks. Another parameter that can be configured in this module is the standard deviation *(sv)* for the random values around each agent's internal parameters.

Simulation module. The user sets the number of simulations to be performed, and then the system starts the simulations.

Results module. This component shows the results of the team's behaviour. This component includes some graphics to ease the interpretation of the data generated by the simulations, i.e. graphical statistics of information such as the average performance of the work team and of each agent.

In the configuration module the user must select the type of agent that he/she wants to create (Project Manager, Engineer, Technician or Assistant). After that, all the internal parameters of the agent must be set, and finally the agent is created (see figure 3.1).

Once the agent is created, the interface allows the user to see and modify the internal parameters of the agent, or if necessary, delete an agent. The prototype allows the user to save the configuration team for future use.

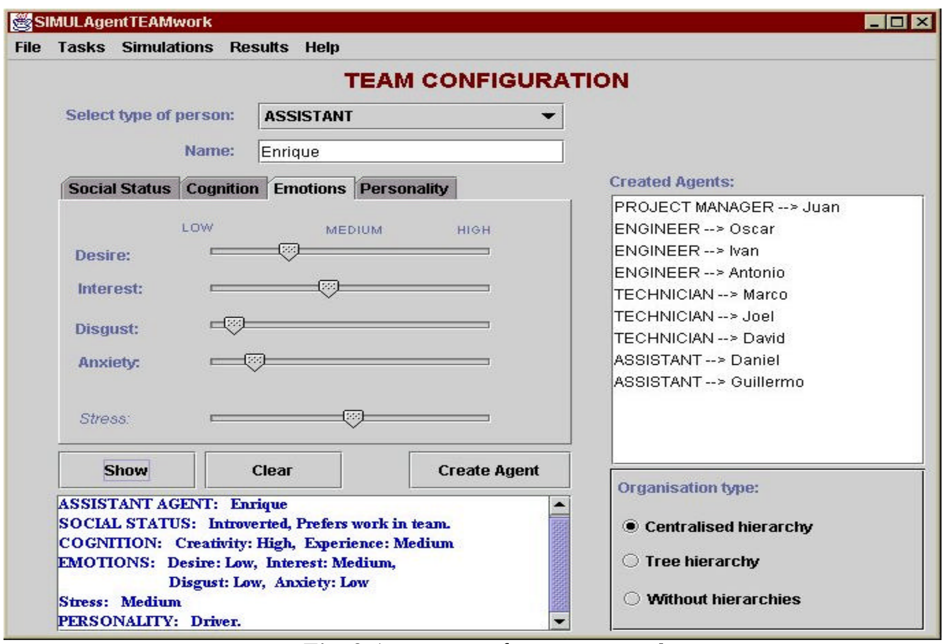

Fig. 3.1. Team configuration window

The window shown in Figure 3.2 allows the user to set the tasks that form the project to be developed by the team. When a task is created, all its parameters must be set.

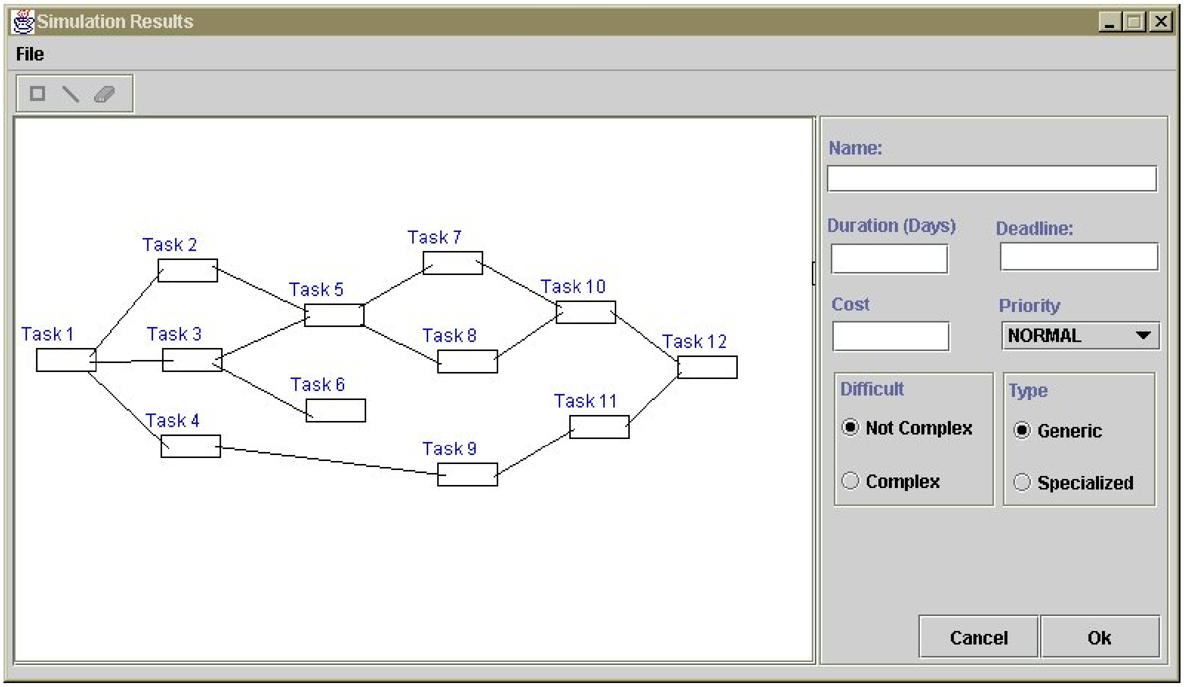

Fig. 3.2. Project configuration window.

When a task precedes another task, a line between both tasks represents this relationship. One of the advantages of the tool is that all the configuration process is made graphically. Similar to a team configuration, a project can be saved for future references.

The last module before the simulations start is the tasks assignment. Currently the user assigns the tasks to their respective team members, but in future, the project manager agent will have the capability to modify these assignments at run time. At this point, the user can start the simulation step by setting the number of simulations.

Finally, in the results module the user can consult what was the team behaviour through the project. We have implemented three different graphical forms to show the results. The user can observe the average duration of the project and the specific average duration of each task. Similarly the system presents graphically the average quality of each task. In addition, the user can select any task in the graphic and get the internal information of this task and see which were the agents in charge of it (see Figure 3.3).

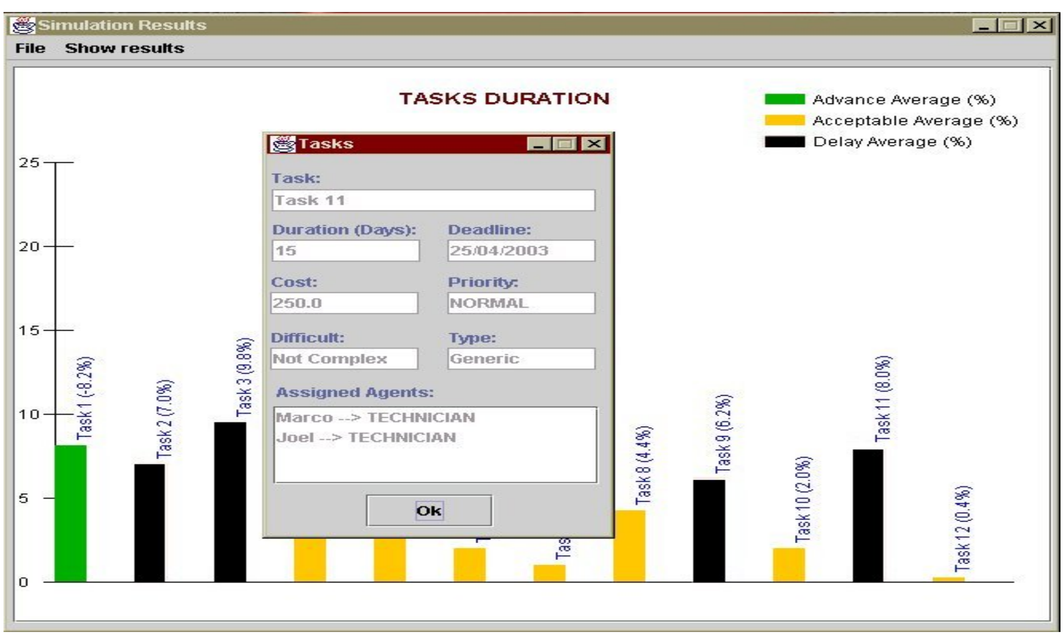

Fig. 3.3. Results window.

The other graphical result is the information about the agent's behaviour. When the user selects any agent, the system shows the task average quality and average duration for that agent over all its assigned tasks. In future versions of the tool, several views will be implemented, such as graphics about the real duration of the tasks within the system (in days), information about the best and worst behaviour of agents at specific times, etc. All this information will help the user to take the most suitable decisions about the configuration of a real work team.

4. Initial Results

In this section we present our first results obtained in the prototype. The system receives as input two "types of information": the *configuration team* with its internal state, and the *project* assigned to the team (taking into account the internal characteristics of each task and the assignment of these tasks to each agent). The output of the system is the average of *task advance or task delay*, and the *average quality* of each performed task.

The work team was configured in a first case study with 10 team members: 1 Project Manager, 3 Engineers, 3 Technicians and 3 Assistants. The internal characteristics of these agents were set randomly and the values are shown in Table 4.1.

Agent Name: Juan **Type:** Project Manager. **Social Status:** Introverted; prefers to work alone. **Cognition:** Creativity-*High*; Experience-*High*. **Emotions:** Desire-*High*; Interest-*High*; Disgust-*Low*; Anxiety-*Low*; Stress-*Low.* **Personality:** Expressive. **Assigned tasks:** Task 1; Task 10.
Agent Name: Oscar **Type:** Engineer. **Social Status:** Extroverted; prefers to work in team. **Cognition:** Creativity-*Medium*, Experience-*Low*. **Emotions:** Desire-*Low*; Interest-*Low*; Disgust-*Medium*; Anxiety-*High*; Stress-*High.* **Personality:** Driver. **Assigned tasks:** Task 8.
Agent Name: Ivan **Type:** Engineer. **Social Status:** Introverted; Prefers to work alone. **Cognition:** Creativity-*High*; Experience-*Medium*. **Emotions:** Desire-*Medium*; Interest-*High*; Disgust-*Low*; Anxiety-*Low*; Stress-*High*. **Personality:** Analytical. **Assigned tasks:** Task 3; Task 5; Task 12.
Agent Name: Antonio **Type:** Engineer. **Social Status:** Introverted; Prefers to work alone. **Cognition:** Creativity-*Medium*; Experience-*High*. **Emotions:** Desire-*High*; Interest-*High*; Disgust-*Low*; Anxiety-*Low*; Stress-*Low*. **Personality:** Amiable. **Assigned tasks:** Task 4; Task 5; Task 10.
Agent Name: Marco **Type:** Technician. **Social Status:** Introverted; Prefers to work alone. **Cognition:** Creativity-*Medium*; Experience-*Medium*. **Emotions:** Desire-*High*; Interest-*Medium*; Disgust-*Medium*; Anxiety-*Low*; Stress-*Low*. **Personality:** Amiable. **Assigned tasks:** Task 3; Task 5; Task 7; Task 11
Agent Name: Joel **Type:** Technician. **Social Status:** Extroverted; Prefers to work alone **Cognition:** Creativity-*Medium*; Experience-*High*. **Emotions:** Desire-*High*; Interest-*High*; Disgust-*High*; Anxiety-*High*; Stress-*Medium*. **Personality:** Driver. **Assigned tasks:** Task 2; Task 4; Task 11.

Agent Name: David
Type: Technician. **Social Status:** Introverted; Prefers to work alone **Cognition:** Creativity-*Medium*; Experience-*Medium*. **Emotions:** Desire-*High*; Interest-*High*; Disgust-*Low*; Anxiety-*Low*; Stress-*Low.* **Personality:** Driver. **Assigned tasks:** Task 7; Task 10.
Agent Name: Daniel
Type: Assistant. **Social Status:** Extroverted; Prefers to work alone **Cognition:** Creativity-*Medium*; Experience-*High*. **Emotions:** Desire-*High*; Interest-*High*; Disgust-*Low*; Anxiety-*Medium*; Stress-*Low*. **Personality:** Driver. **Assigned tasks:** Task 4; Task 6; Task 8; Task 12
Agent Name: Guillermo
Type: Assistant. **Social Status:** Extroverted; Prefers to work in team. **Cognition:** Creativity-*High*; Experience-*Medium* **Emotions:** Desire-*Low*; Interest-*Low*; Disgust-*Medium*; Anxiety-*High*; Stress-*High*. **Personality:** Driver. **Assigned tasks:** Task 2; Task 5; Task 9.
Agent Name: Enrique
Type: Assistant. **Social Status:** Extroverted; Prefers to work alone **Cognition:** Creativity-*Low*; Experience-*Low.* **Emotions:** Desire-*Low*; Interest-*Low*; Disgust-*High*; Anxiety-*High*; Stress-*High*. **Personality:** Expressive. **Assigned tasks:** Task 3.

Table 4.1. Team Members Configuration.

We have assigned a project with 12 tasks to this team. The characteristics of each task are described in Table 4.2. We must say that the tasks characteristics were selected randomly and do not represent a real project.

Name	Difficult	Type	Precedes
Task 1	Complex	Specialised	Task 2 Task 3 Task 4
Task 2	Complex	Generic	Task 5
Task 3	Not Complex	Specialised	Task 5 Task 6
Task 4	Complex	Specialised	Task 9
Task 5	Complex	Generic	Task 7 Task 8
Task 6	Complex	Generic	
Task 7	Not Complex	Specialised	Task 10
Task 8	Complex	Generic	Task 10
Task 9	Not Complex	Generic	Task 11
Task 10	Complex	Generic	Task 12
Task 11	Not Complex	Generic	Task 12
Task 12	Not Complex	Specialised	

Table 4.2. Project configuration.

With these input information we developed 50 simulations and we observe that:

- The most delayed tasks were those that have been performed by agents with high or medium values in the stress, anxiety and disgust parameters, even when the values of desire and interest were medium or high (see Task 2, Task

3, Task 9 and Task 11 in Fig 4.1), the agents with this behaviour in our case study were the agents Ivan and Guillermo.

- The tasks with high degree of completion were those that have been performed by agents with high values in the interest and desire parameters, and medium-low values in the disgust and anxiety parameters, for example the agents Juan and Daniel (see Task 1 and Task 12 in Fig. 4.1).

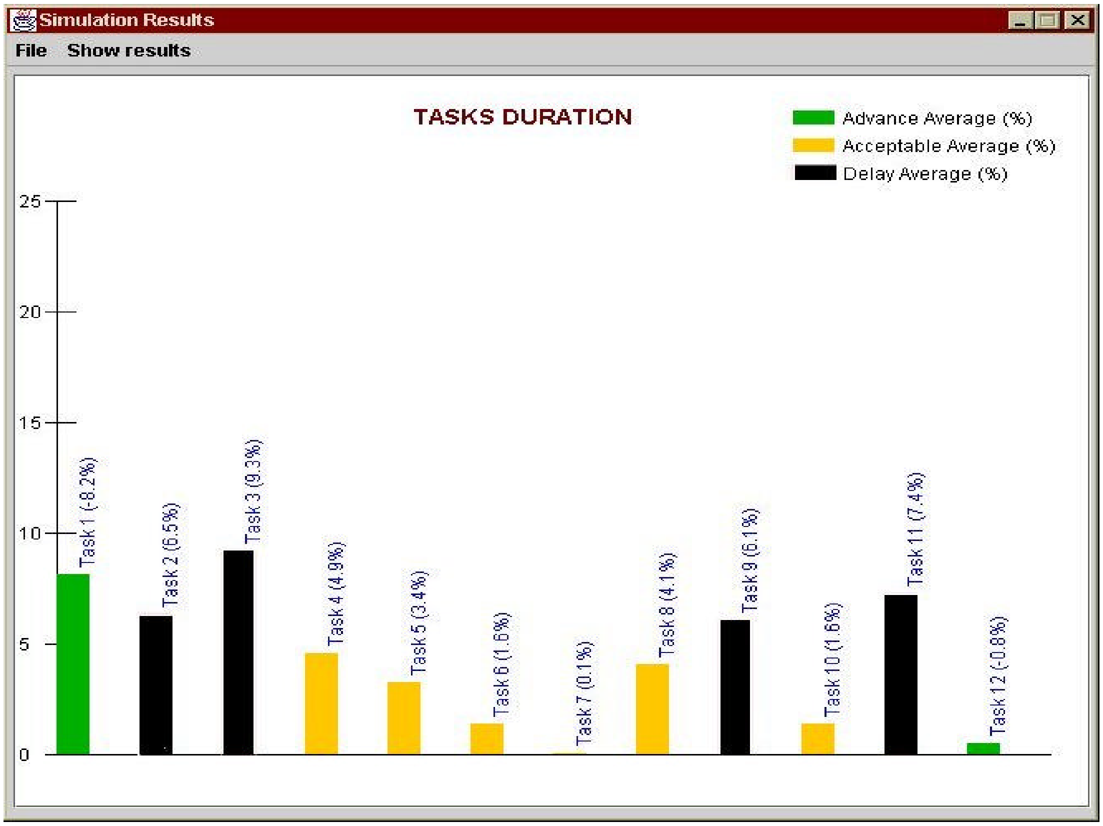

Fig. 4.1. Average task duration after 50 simulations.

- Tasks with low average quality were performed by agents with high or medium stress faced with a complex difficult task. Nevertheless, the quality of a task is less affected by the internal parameters of the agents than its duration.

- The tasks with high average quality were made by agents with high values of the interest and desire parameters and low values of the stress, disgust and anxiety parameters. The agents with the best average quality were the agents Juan, Antonio and David.

After these 50 simulations several modifications were made to the team. On the one hand the internal parameters of each agent were modified (raising and/or lowering the value in one or more emotions parameters, changing its social features and changing the values in its cognition component). On the other hand some agents were assigned or removed from some of the tasks.

After 50 simulations with every change, we observed the following results:

- When an agent is assigned or removed from one task, if this agent has similar internal parameters to its task-mates, the result in the task is almost the same. On the other hand, if the internal parameters of the agent are too different from those of the other agents assigned to that task, then the change in the task result is relevant.

- When the emotional state of the agent is balanced (the values of the interest and desire are *medium* or *high*, and the values of the disgust, anxiety are *low* or *medium*) the task average duration is *acceptable* and the task quality is *high*.

- When one agent with *high* stress and *low* desire and interest is removed from a given task, and its tem-mates with *low* or *medium* stress and *medium* or *high* interest and desire are still working on the task, then the task average duration is decreased. We removed the agent Enrique from task 3 (the one with the highest delay in the first 50 simulations) and the average duration was improved.

- The agent stress parameter has a great influence in the task duration result. When the stress is *high* the average task duration increases and when is *low*, the task duration decreases. The task quality is influenced like the duration by the stress but in a lesser degree. In this case study we decrease the stress parameter for the Enrique and Ivan agents. The average duration was decreased and the average quality of their assigned tasks was increased.

- The agent creativity parameter has influence in the task result only when the task type is *specialised*.

- When the individual emotional parameters of the agents could generate a bad result in their tasks (i.e. high or medium stress, high or medium anxiety, high or medium disgust, and low or medium interest, low or medium desire) but they work together in a same task, two possible changes in the task results occur. If all the agents prefer to work in a team, then the task duration decreases and the task quality increases. On the contrary, if all the agents prefers to work alone and they are working in a given task together, the task average duration increases and the task quality decreases.

- When the agent prefers to work in a team but is working alone in a task, the task duration is more affected than the task quality. This could be observed with the agent Guillermo and its assigned task 9.

- Tasks in charge of agents with *analytical* and *driver* personality got the best average quality and duration. For example we put the agents Ivan and Daniel together in task 12 and the average duration was –0.8% (negative value means advance) and average quality was 96%, even the stress parameter of Ivan was *high* and desire was *medium*.

It could be argued that these results could be expected a priori given the way in which the agent's behaviour is generated, they are, nevertheless a solid basis to add more complexity to the model of a team.

5. Conclusions and Future Work

In this paper we have discussed the agent-base model that we are developing to support the configuration of work teams. Our proposed model includes emotional and personality traits for modelling human behaviour. The model also includes a basic task representation. The human behaviour is generated from the interaction between team-members and its assigned tasks. We have presented the development of a first prototype that implements our model and some initial results obtained were also presented.

Nevertheless there are some work that are yet to be developed to complete this research. There are several aspects that need to be taken into account to build a solid and reliable agent-based tool. We have divided the job to be done in the following points:

1.- Improve our model. We must tune the values of our emotional parameters in order to get the most suitable proportionality between our proposed parameters and real life. We also have to analyse if there are other emotions that must be taken into account. To achieve this goal some sensitivity analysis over our parameters should be done backed with information from a real team.

2.- Test our model with a real team in a real project. This part is one of the most important work that we must do. Our model can be validated by testing it with real information or by asking an expert to validate it. We will be able to observe whether the emotions have the influence in human behaviour that we are proposing or not. We must also improve our task model by taking into account any other relevant information that affects the behaviour of the agents. With these tests we could make the sensitivity analysis and enhance our emotions model as we explained below.

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