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Collaborative Decision Making Amongst Human and Artificial Beings

Daniel I. Thomas and Ljubo B. Vlacic

Intelligent Control Systems Laboratory, Griffith University, Australia,
Daniel_Thomas@TechnologyOneCorp.com; L.Vlacic@griffith.edu.au

Summary. This chapter provides an overview of collaborative decision making between human and artificial beings. The chapter presents concepts, examples and scenarios that can assist in designing collaborative systems mixing humans and artificial beings as fully equal partners (FEPs). Human and artificial beings are demonstrated performing tasks cooperatively with each other, while being fully replaceable or interchangeable with other beings regardless of their biological or artificial nature. These beings are also not necessarily aware whether his/her/its game partners are human or artificial. This is not to say that FEPs are equal in decision making abilities, but rather that these partners possess an equal communication ability. As a result, a game player is not aware whether his/her game partner is a human or artificial being.

Also outlined is the collaborative process and how this process allows FEPs to collaborate in a structured manner. Once defined, a simple practical example of a collaborative FEPs system is demonstrated: the electronic meeting room. Shown step by step are the processes and values used to arrive at the final outcome, describing in detail how these human and artificial beings collaborate within the electronic meeting room.

Finally, after working through the play scenario and discussing possible future enhancements, some practical domains where collaborative FEPs are applicable in various industries are defined.

By the end of this chapter the reader should have an understanding of the following topics:

- Understanding the concept of human and artificial beings as collaborative fully equal partners.
- Be introduced to the cognitive elements of artificial beings and how these contribute to constructing a FEPs concept.
- Having been walked through a play scenario example of human and artificial being collaboration, will have the necessary resources to create their own play scenarios.
- Be aware of a number of practical applications for collaborative FEPs in industry applications such as Online Training and Education, Human Resources, Project Management, Transportation and Socially Oriented Computer Games for clinical psychology and behavioral studies.

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4.1 Introduction

With billions of dollars spent annually on computer game entertainment (Beinisch et al., 2005), there is nobody that can contest the fact that the computer games industry is a serious business. Most intriguing about these figures is the rise of massively multiplayer online (MMO) games as a significant game type. According to this OECD report prepared by Beinisch et al., the attracting factor of this game type is its socially-oriented gaming experience.

Given the social aspect of these games, enhancing the social and collaborative experience would increase the attractiveness of MMO games. Interestingly, augmenting the social and collaborative nature of games (as entertainment) can also provide an enhanced learning experience for educational and training games based upon similar concepts.

We propose that one method to augment the social and collaborative nature of educational and training games is by using artificial beings as fully equal partners. In this chapter, we define how human and artificial beings may effectively collaborate with each other in a socially-oriented setting.

In Sect. 1, we define what a collaborative fully equal partner (FEP) is, and how this concept can enhance a computer game based on a social setting followed by Sect. 2 describing the architecture and attributes of a collaborative computer game supporting FEPs.

In Sect. 3, we apply these principles and describe a simple collaborative process based upon the social interactions of the beings within the computer game scenario.

Collaborative FEP concepts provide a compelling collaborative decision-making concept when applied to the various challenges faced within industry. In Sect. 4 we describe some of these possible applications.

By the end of this chapter, it is expected that the reader shall have an understanding of collaborative FEPs, collaborative principles and how to apply these principles in simple group decision-making situations. We see computer games as a setting that enables modeling an embodiment of interactive group decision making and collaborative work environments that may occur within the physical world.

4.2 Humans and Artificial Beings: Fully Equal Partners

There have been many instances in the past where artificial players have controlled an in-game character as a human would (Laird, 2001). In these instances, the artificial player has typically participated as an opponent. In addition, there are many games where simple artificial players have worked as part of a human player's "team" where they interact with these entities through simple commands.

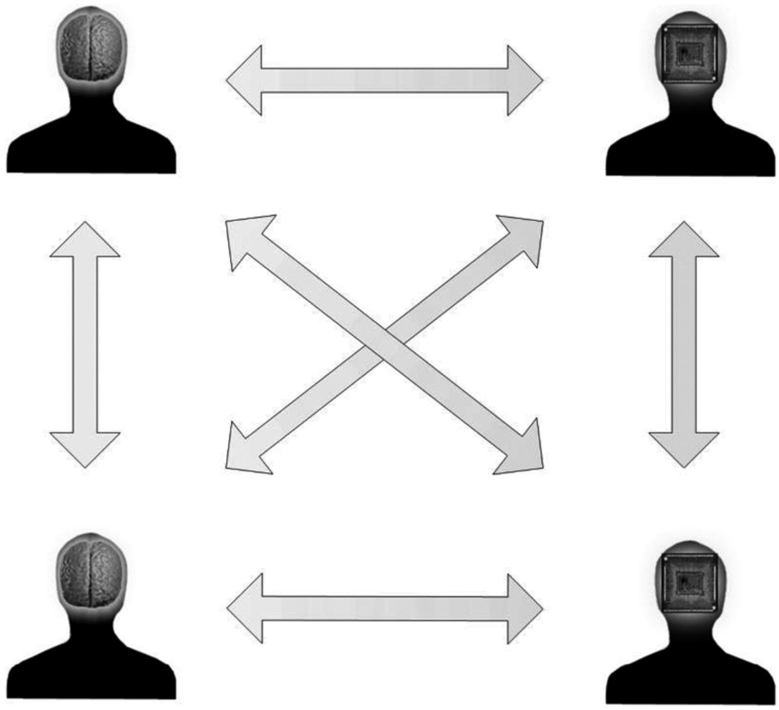

Fig. 4.1. Humans and Artificial beings as collaborative FEPs

Building upon these principles, we consider that if artificial players were able to participate and collaborate within a computer game setting, while having their own internal goals (that is, the ability to play a game as a human would), that these games would have an increased perception of realism and "life" as the interactions between human and artificial beings is not static, scripted or based upon the scenario at hand, but rather changes as these beings interact and collaborate with each other over time to affect change upon the game world that they are situated within.

To this end, we propose a FEP concept (Fig. 4.1) where human and artificial beings collaborate to achieve game goals. We consider this concept as complementary to other uses of autonomous agents as opponents (Laird, 2001) or as interactive story characters (Magerko et al., 2004). Unlike our concept, non-player characters are typically able to work with (or provide simple assistance to) the human players, but do not participate as intelligent collaborative entities, equal in ability to a human being.

A FEP within the context of collaborative computer games:

- Can work cooperatively with other FEP beings (human and artificial) and within the context of computer games;
- "Play" the game as a human would; and

- Does not work to a predefined script or take direction from an agent "director" (Magerko et al., 2004; Riedl et al., 2003).

In addition, collaborative FEPs exhibit the common traits of an autonomous agent. As we consider both human and artificial beings transparently as entities within a collaborative computer game, we find the concept of an agent described by Jennings and Wooldridge (1995) appropriate for application to the characteristics of collaborative FEPs. Therefore, a FEP, being situated within a collaborative computer game enjoys the following abilities:

1. Are Autonomous; operating without the direct intervention of humans or other entities, having control over their internal state.
2. Situated in, and aware of their environment (the game) and are able to interact with this environment through their sensors and effectors.
3. Have some kind of Social Ability; interacting with other human and artificial beings via the use of a communication language.
4. Is able to perceive changes within the (game) environment and react to these changes in a timely fashion.
5. Agents are also Proactive; being able to exhibit goal-directed behavior (taking the initiative) and directly affecting the game and other entities in order to achieve these goals.

Put in more concisely, a FEP (human or artificial) performs tasks cooperatively with other human or artificial beings and is fully replaceable or interchangeable with another FEP. In addition, a being does not know whether his/her/its game partner is a human or artificial being.

4.2.1 Architecture

In our work with collaborative computer games, we see a collaborative computer game architecture consisting of three distinct layers (Fig. 4.2). This layered approach allows us to formalize the necessary attributes required starting from atomic technical concepts through to abstract concepts of the cognitive layer. Since each layer creates an additional abstraction built upon the previous layer, it is important to provide a firm understanding of each layer's function within a collaborative computer game.

We refer to our approach to a layered collaborative computer game architecture for FEPs as the TeamMATE Architecture (Thomas and Vlacic, 2005). Each layer of the TeamMATE Architecture is described in the following sections, demonstrating how this layered approach to collaborative FEPs permits a socially driven environment to exist comprising of human and artificial partners in a heterogeneous relationship.

Before each of the layers of a collaborative FEP system are discussed, it is important to add that in the context of this chapter the term Layer has been used to describe a particular level of the proposed architecture. We believe that the layers put forward here for collaborative computer game architectures

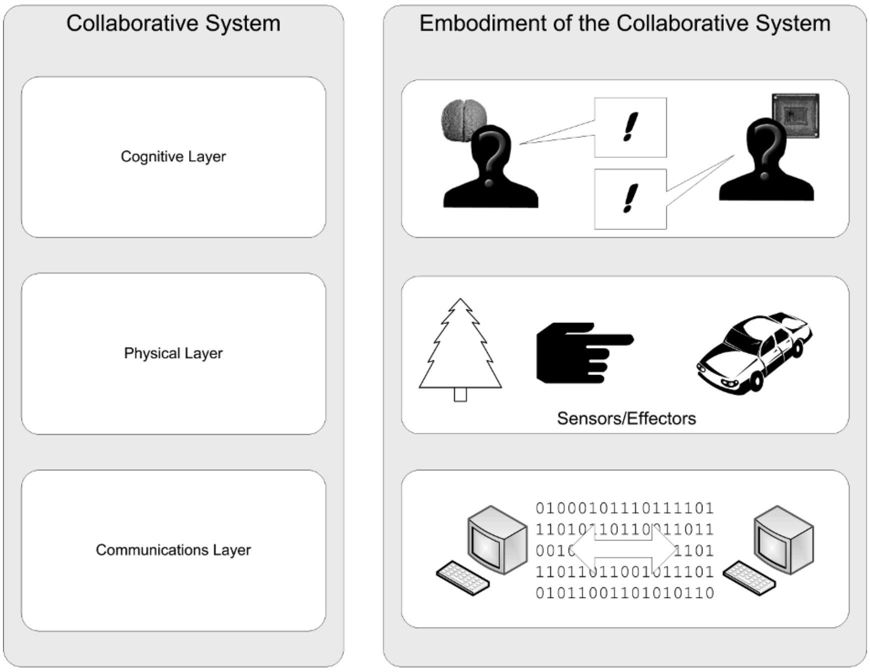

Fig. 4.2. The three architectural layers of a collaborative FEP system

can co-exist with other notions of a layered architecture that deal specifically with the intelligent elements of such a system.

Communication Layer

The communication layer is a very fundamental element of a collaborative computer game. This layer defines the technical protocols used to convey information from the game or other entities from or to the FEP beings situated within the computer game.

The communication layer is effectively a low level transport layer used to pass information from one place to another for example: DirectPlay, TCP/IP, radio signal etc. These protocols, along with the format of the data being transmitted are then available to a FEP's sensors. A FEP may also transmit using these communication protocols via their defined effectors.

Physical Layers

The physical layer within a collaborative computer game defines a FEP's available sensors and effectors within the context of the game. The term "physical" is used to refer to this layer as it defines the characteristics of sensors, effectors and entities within the computer game. Before we are able to work with

Table 4.1. Simplistic physical layer rules

Object	Available actions
Chair	Sit, stand, move
Table	Place item, pick item
Telephone	Call, hang up, speakerphone, listen
Stock	Buy, sell, report
Talk	Whisper, tell all, listen

the more abstract cognitive layers of TeamMATE, it is necessary to define a layer that:

1. Is able to define the physical objects of the collaborative computer game;
2. Provides a common pattern of sensor and effector abilities available to human and artificial beings situated within the game and;
3. Defines the possible actions that may be performed using the available sensors and effectors.

Human and artificial partners must be able to work with the appropriate rules/ constraints of the specific play scenario being undertaken. Physical rules for a given play scenario consist of information about objects in the computer game and how they may be used. Using or enacting some change upon an entity using the defined effectors is referred to as performing an Action. Take as an example, a simple play scenario that contains these physical layer rules (Table 4.1).

When working with more complex games, and also collaborative games that may occur within the physical world, defining all objects and all actions is not feasible. However, it is possible to define the available sensors and effectors for a FEP, while the task of relating objects and actions becomes a function of the cognitive layer.

While a collaborative computer game and the human and artificial beings that are situated within a given play scenario may share a common physical layer, it is not necessarily required that the manifestation of the physical layer will be the same.

For example, in order for a human being to interact with the sensors and effectors provided by the physical layer, it would be necessary to provide a mechanism to interact with the sensors and effectors through a human user interface. Likewise, if an artificial FEP was to interact with other beings within a collaborative computer game, the physical layer would possibly be accessed as some form of software interface.

Cognitive Layer

Having defined FEPs, the communication layer and the physical layer, it is now possible to present the cognitive layer as the third and most sophisticated layer of a collaborative FEP architecture.

The cognitive layer describes the intelligent mechanisms within a human or artificial being that are capable of manipulating, communicating and collaborating intelligently using the defined sensors and effectors provided by the physical layer.

While detailed elaboration of the cognitive layer is beyond the scope of this chapter, we will still briefly touch upon key areas of the cognitive layer: goals, roles and a process for collaboration.

Goals

Understanding the various types of goals that can exist within a collaborative computer game is imperative to understanding the outcomes of the game. Typically, the goals that can be found in such a game are: individual goals, goals of the collective (group) scenario and goals of the play scenario.

In Sect. 3, we have simplified the goal behavior of the play scenario to simply be a single goal defined for the entire play scenario. More complex goal structures within the context of the cognitive layer are beyond the scope of this chapter.

Roles

Roles are the ingredients of a linking mechanism between the cognitive layer and the physical layer. Within the collaborative FEP architecture, roles define specific functions or duties to be performed by FEPs fulfilling the role. A FEP's role can also affect the sensors and effectors available to the being participating in the game.

While our collaborative computer game concept has been designed to operate without the assistance of an overall agent "director", as is the case with work in the field of interactive fiction games (Magerko et al., 2004), we have developed an authority role – The Leader.

The Leader typically is responsible for the organization, initiation and conclusion of a play scenario or defined objective within a collaborative computer game. A Leader may have to organize a team for a single task or may have to organize groups of FEPs over the entire play time of the game.

Depending on how the collaborative computer game has been designed, multiple roles can be defined. In keeping with the *FEP* concept, a human or artificial being is permitted to perform any role defined.

A Collaborative Process

The collaborative process is used to facilitate a formalized process for collaboration during the lifetime of a play scenario. The process draws upon the use of sensors and effectors defined by the physical layer to guide the collaborative processes of a FEP's cognitive layer. The following figure (Fig. 4.3) defines the collaborative process employed within the cognitive layer allowing the participating FEPs to effectively collaborate:

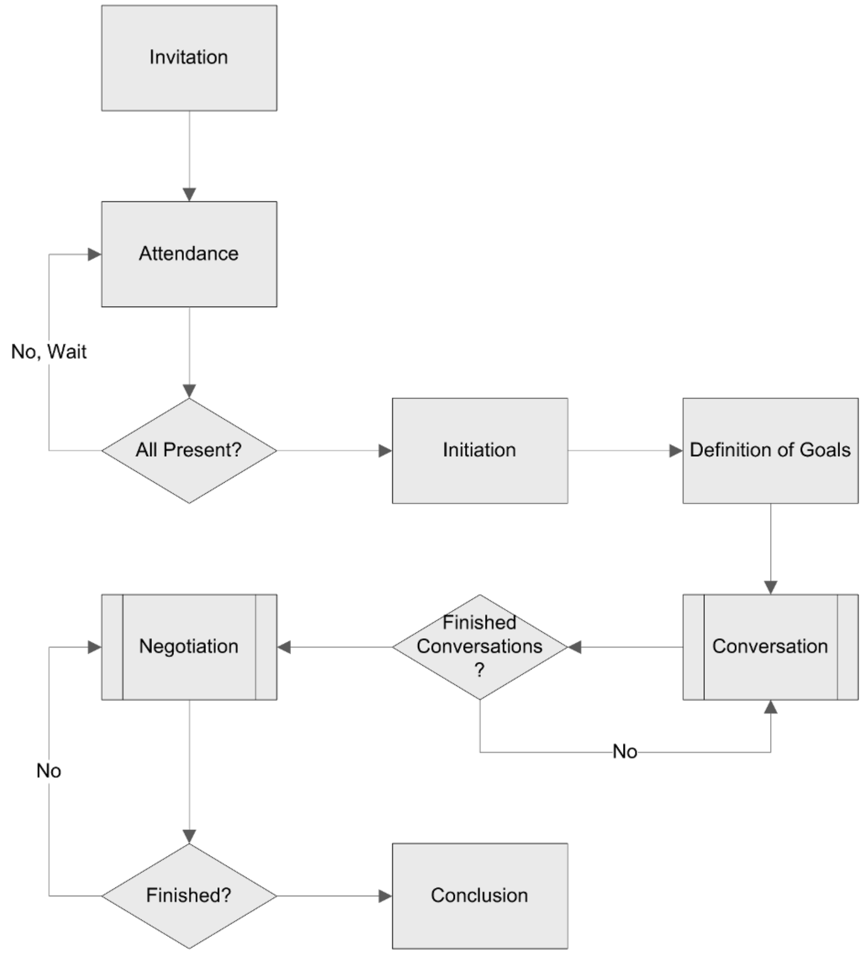

Fig. 4.3. The collaborative process

Invitation

While this phase is not relevant to our current work it bears mentioning that in a collaborative computer game, participation may be by invitation. This process can also include the scheduling of a pre-defined “play time” as well as the roles of the invited FEPs.

Attendance

Once a collaborative computer game has been initiated, participating FEPs are able to “join” the game. Attendance can also occur internally, as human and artificial beings already participating within the game may attend and participate in many play scenarios within the collaborative computer game.

Initiation

At a point determined by the leader (typically when all participants are present, or the scheduled meeting time has been reached) they will declare the play scenario "started". It is at this point that the play scenario can commence. Initiation of the play scenario is actually a special action (we describe actions in more detail later).

Definition of Goals

Before any meaningful collaboration can be achieved between the participating FEPs, it is necessary to define the goals of the current play scenario. This defines the framework for the conversations that will occur during the process. These goals can also be used to determine the success or failure of a particular play scenario (or whether additional play is required).

Presentation

All communication and collaborative behavior within the computer game takes place in the form of "Conversations". Conversations involve the presentation of some instructions, positions, statements, or questions that require additional facts and opinions from the FEPs involved in the collaborative process.

The presentation step may involve physical actions or statements by the partners.

Negotiation

Negotiation involves the willingness of one or more parties involved in the conversation to accept a compromised position. In the collaborative process, this involves the interpretation of the Truth/Facts revealed during the conversation process. As the conversations occur, partners are able to collect truths as well as opinions/positions stated by the other partners. These collected facts or collaborative group knowledge, is then used to feed the negotiation process that attempts to create outcomes based upon the earlier stated goals of the collaborative process.

The negotiation process involves the process of conversation that the partners engage in and allows the FEPs to discover a best fit outcome based upon the goals stated during the definition of goals phase.

Another important factor is how influence plays a role in the interpretation/ negotiation process. The following elements are considered part of the negotiation process.

Questions

Questions are used to obtain truths, facts and perceptions. Questions in a collaborative computer game are any communications made by FEPs that result in an outcome (for simplicity, statements or instructions are also considered "questions"). When an agent proposes a question, there are three possible outcomes: A response (which may be itself another question), an Action or No Response.

Response

A response is given when a FEP receives a directed question, or perceives (through their sensors) the necessity to respond to a question or action. As a response may happen through non-directed communication, but through the perception of other events within the collaborative computer game, a response may itself initiate a new conversation/negotiation. A special type of response that requires the use of effectors not directly related to inter being communication is called an Action.

Actions

Actions are special responses to questions that result in a transition of some item or process from one state to another. For example, if a FEP asked the question "I require a technician for Project X", a possible resulting outcome may be that another participant in the play scenario may perform an action that results in the commencement of a recruitment process to hire a skilled technician for Project X.

Actions tie the collaborative process to the defined physical layer as only those actions available within the physical layer may be enacted to change a defined entity's state. Thus, the introduction of cognitive layer elements results in the ability to enact complex/abstract actions based on perceived physical layer effectors rather than a defined set of actions available for a defined role being enacted by a FEP.

No Response

In some instances, a question may not require a response.

Influence

Collaborative FEPs may create an affinity with one or more entities and are more likely to accept their position during negotiation. Possible methods for obtaining an affinity with one or more FEPs include:

1. The degree to which one FEP's responses convey a perception/opinion that matches that of another FEP. The more that one partner's position matches that of another partner, it becomes more likely that the partner will "trust" the statements of that partner.

2. Some arbitrary influence factor that has the partner tending towards the position of one or more other partners.
3. A pre-existing relationship (for example a friendship) that exists beyond the scope of the collaborative process.

Conclusion

At either a specified time, or when the objectives of the play scenario have been completed successfully, the leader is able to enact a special action that concludes the play scenario.

Prior to the conclusion, the leader or another nominated partner is given the opportunity to summarize or present the outcomes of the scenario to the other participating human and artificial beings. Outcomes can include gauging the success/failure of the play scenario based on the goals defined at the beginning by the leader; can also result on actions required beyond the scope of the current play scenario and could also be the determination that additional play scenarios are required.

Breaking Down the Collaborative Process

Consider a group of FEPs P engaged in the collaborative process c. There will be a set of outcomes O met at the conclusion of the process. The set is based upon the set of defined goals G defined at the beginning of the process and the ability of the partners to collaborate towards the desired outcomes. However there is not a 1:1 ratio of outcomes to goals, and the set of objectives may even be empty.

$$O = c(P, G). \tag{4.1}$$

Each partner p_k is either Human h_i or Artificial a_j. The collaborative group is the union of the human and artificial FEPs.

$$\begin{aligned} P &= \{p_1, .., p_k\} \\ p_k &= \{h_i | a_j\} \\ A &= \{a_1, .., a_j\} \\ H &= \{h_1, .., h_i\} \\ P &= A \cup H \end{aligned} \tag{4.2}$$

During the collaborative process, any partner p_l, where $\mathrm{l} \neq \mathrm{k}$, may ask a question q_m of any other partner p_k in order to receive a response r_m, where $\mathrm{m} = \mathrm{j} + \mathrm{i}$

$$\begin{aligned} r_m = f(p_k, q_m) \text{ where } q_m = g(p_l), \\ r_m = f(p_k, g(p_l)). \end{aligned} \tag{4.3}$$

The response may contain facts or partial knowledge that can be collected and added to the collective knowledge obtained by the group. The collaborative process of the group in order to obtain a set of outcomes is then consensus based upon the interpretation of the group collective knowledge in order to identify whether the partners have achieved (or partially achieved) the initial goals of the group.

The set of *Group Collective Knowledge* K obtained by the group through the collaborative process is a subset of the responses obtained during the collaborative process.

$$\begin{aligned} &K \subseteq R \\ &K \subseteq \{r_1, .., r_m\} \\ &\{k_1, ..k_q\} \subseteq \{r_1, .., r_m\} \end{aligned} \tag{4.4}$$

For simplicity, assume that all responses r_m are components of group collective knowledge $K = R$. This means that all results contribute to the set of collective knowledge and that all partners are aware of this knowledge.

$$\begin{aligned} &K = R \\ &\{k_1, .., k_q\} = \{r_1, .., r_m\} \\ &\quad \text{i.e. } q = m \end{aligned} \tag{4.5}$$

Outcomes of the collaborative group are a result of the collaborative process between the group of FEPs and the goals of the collaborative process.

$$\begin{aligned} &O = c(P, G) \\ &O = c(P, G) \\ &O = \{o_1, .., o_n\} \\ &o_n = s(P, n(G, K^P)) \end{aligned} \tag{4.6}$$

where s is a function of all partners P applied to an interpretation function n of the set of goals G, the set of group collective knowledge across the entire set of partners K^P, resulting in an outcome o_n.

4.2.2 A Fuzzy Approach

We have established a formal process by which a collaborative action may take place. What we have not yet discussed is how FEPs within this process are to able make individual intelligent decisions nor at a collaborative decision level.

While it is safe to assume that every human FEP within a collaborative computer game is able to make decisions for himself/herself, in order to create our own play scenario, we need to define how our artificial beings may intelligently assess the information that they receive.

For our purposes, we have selected a fuzzy approach to decision making. The reasons for this decision were its ability to model complex or ill-structured problems, the way in which fuzzy rules can be formulated in an easy to follow IF-THEN manner and its use of human expert knowledge to model the decision making rules.

While more advanced intelligent/learning methodologies could have been used, by selecting fuzzy decision making it is hoped that it will allow a larger audience of multiple skill levels to begin creating FEP systems.

Fuzzy Logic: A Brief Overview

Fuzzy logic is a problem solving concept that enables the use of human heuristic knowledge about a given problem and is capable of solving ill-defined problems. In traditional Boolean logic, answers are either true or false. When dealing with a fuzzy logic, a value may still effectively evaluate to true (1) or false (0), but may also evaluate to any value between the two, giving us "partially true" or "mostly true" values. It is this concept that makes fuzzy logic a useful tool when dealing with complex problems. Fuzzy rules can simplify complex processes by evaluating inputs in order to achieve "best fit" outputs without the need to have exhaustive/complete knowledge of the process. This concept mimics how humans solve problems using heuristic knowledge.

Fuzzy systems encapsulate human expert knowledge of a problem in simplified descriptive rules. The language that is used to describe attributes of a fuzzy system has a certain vagueness to it (hence the use of the term fuzzy) as the language that is used to articulate an attribute's magnitude may apply to more or less of a degree to the attribute being described. Words that are used to describe attributes in a Fuzzy System reflect the way that humans articulate magnitudes. Words such as "cool", "old" and "slow" are used to describe values and are known as *Linguistic Terms*. Just like human experts would describe a value, a linguistic term can describe any input value referred to as a *Crisp Value*, over the universe of discourse. A crisp value however, is more accurately described by some terms than others. This is known as the *Degree of Membership* (DOM) to which a crisp value falls within the range of a linguistic term. For example, Table 4.2 shows a five term linguistic variable for the temperature required to brew coffee:

The DOM to which a crisp value falls within a linguistic term is taken over a numeric range of zero to one.

Table 4.2. Linguistic variable temperature and its terms

Crisp value (temperature, °C)	Linguistic term	DOM
≤87	Cold	0
88	Warm	0.25
93	Brewable	0.5
98	Hot	0.75
≥98	Boiling	1

In order to describe attributes as linguistic terms, the original input values, referred to as *Crisp Values*, are *Fuzzified* and articulated as linguistic variables, for example "temperature", "age" and "speed".

Once fuzzy rules have been applied and there is a result (as a linguistic variable), the fuzzy result must then be *Defuzzified* in order to obtain a crisp output value that can then be applied to the problem.

Take for example a control system that regulates the temperature of an automatic coffee machine. If the ideal temperature of the water being used to brew the coffee needs to maintained at 93°C, then the software needs to measure the temperature of the water within the reservoir and either heat it using an element, or turn off the heating element for a certain amount of time. The temperature sensor takes a reading of 89°C (The crisp value). A set of fuzzy rules can be used to describe this process. These rules are described in an IF–THEN form:

IF temperature = warm THEN heating element = medium

In the above example, when the temperature of the water is "warm" the heating element will be turned on for a "medium" amount of time. In the above case, the "medium" may equate to sustaining a current to a heating element for 1 min.

The important thing to remember is that when a crisp value is converted into a linguistic term (for example "cold", "warm", "brewable", "hot", "boiling") it will be evaluated based on the *Degree of Membership* (DOM) that it belongs to each term (Table 4.2).

In this chapter we will be using a multiple input single output (MISO) fuzzy system as opposed to more complex multiple input multiple output (MIMO) systems.

The Fuzzification Process

Fuzzification is the process of converting crisp real-world values into linguistic terms. A crisp value may be a member of a number of linguistic terms. The degree of membership that a crisp value has within any one term is determined by the membership function μ_F. This function can take many forms, but result in obtaining a value between 0 and 1 for the crisp value within the universe of discourse.

In the above example (Fig. 4.4), the membership function for considering a temperature "Hot" has resulted in the crisp value having a degree of membership of 0.75. Each linguistic term has its own membership function. When a crisp value is fuzzified, the degree of membership determines the likeliness of the match between the crisp value and the linguistic term.

There are many types of membership functions that are used to describe a linguistic term. The example in shows a Gaussian-shaped membership function. There are many types of membership functions that may be applied

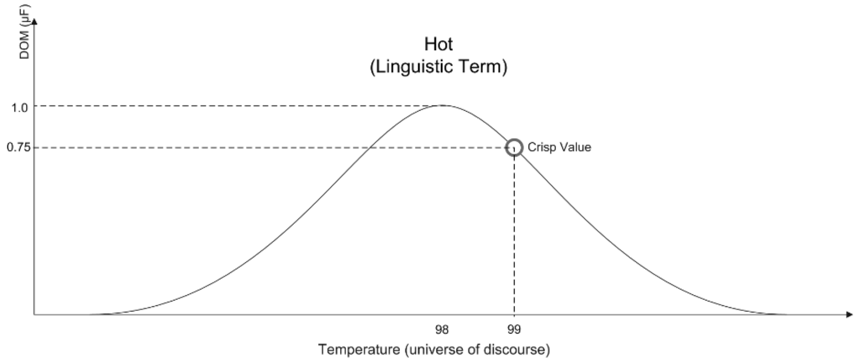

Fig. 4.4. Determining the degree of membership

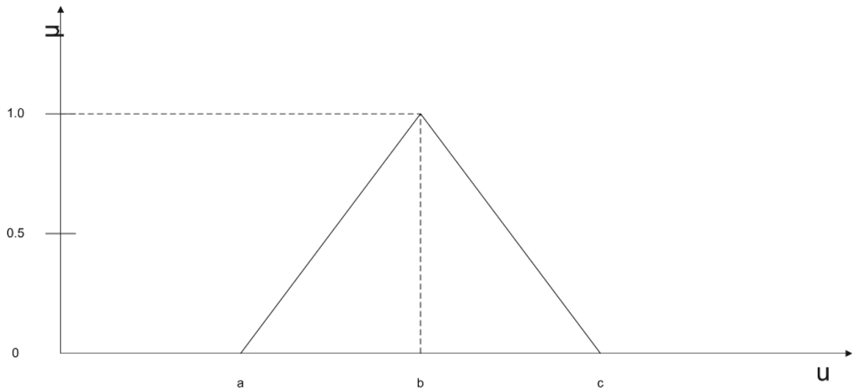

Fig. 4.5. A triangular membership function (T Function)

(they do not even need to be symmetrical); the choice depends upon the application. For the purposes of this chapter and for simplicity, a triangular membership function is used. The triangular membership function (or T-Function) is defined as (Yan et al., 1994):

$$T(u; a, b, c) = \left\{ \begin{array}{c} 0 \\ (u-a)/(b-a) \\ (c-u)/(c-b) \\ 0 \end{array} \right\} \quad \begin{array}{l} \text{For } u < a \\ \text{For } a \leq u \leq b \\ \text{For } b \leq u \leq c \\ \text{For } u > c \end{array} \tag{4.7}$$

Where u is an input value from the universe of discourse, while a and c are the lower and upper bounds of the membership function and b is the midpoint (Fig. 4.5).

Fuzzy Rules

As stated earlier, Fuzzy rules are described in terms of IF–THEN conditions. These rules cover all linguistic terms for the required inputs and matches them to conclusions:

$$IF\ x\ is\ A\ THEN\ y\ is\ B$$

As one can imagine, the more linguistic terms there are for a given universe of discourse (crisp input) and the number inputs greatly affects the size of the rule set. In order to determine to what degree a rule applies to the input parameters, a rule's *fire strength* may be calculated. There are many methods that can be used to determine the fire strength of a rule. One method for determining the fire strength of rule is the MAX-MIN.

The MAX-MIN method of determining the fire strength of a particular rule involves taking the degree of membership values for each input into the rule. The fire strength is then determined by the smallest of the fire strengths.

Defuzzification: Obtaining a "Real" output

Once we have achieved an outcome from the application of the fuzzy rules, the resulting fuzzy set values must be converted into a real crisp value. There are a number of methods for selecting an appropriate crisp value including *Center of Gravity, Max Criterion, Mean of Maximum, Center of Area* and *Center-Average.*

In this chapter a centre of gravity (COG) method has been used to determine an appropriate crisp output. The COG method is used in many fuzzy systems given its low computational cost. To obtain a u^{crisp} value we can apply the following to obtain the center of gravity (Passino and Yurkovich, 1998):

$$u^{crisp} = \frac{\sum_i b_i \int \mu_{(i)}}{\sum_i \int \mu_{(i)}}. \tag{4.8}$$

The function $\int \mu_{(i)}$ is used to represent the function required to calculate the area underneath the fuzzy membership function μ_i (where i indicates the ith rule) and b_i is the position where the membership function is at its peak (i.e. has a value of 1). Since it has been indicated that the triangular membership function shall be used in the fuzzy systems involved with the collaborative process, the calculation of the area underneath the triangular membership function becomes (Passino and Yurkovich, 1998):

$$\int \mu_{(i)} = w\left(h - \frac{h^2}{2}\right), \tag{4.9}$$

where w is the width of the triangle's base and h is the fire strength of the fuzzy rule.

Using Fuzzy Logic in a Collaborative System

Coming back to our collaborative process, there are a number of areas where different fuzzy algorithms may be used within a collaborative group of FEPs. The following section shows how an artificial partner would be able to integrate into a collaborative group of FEPs. This would assist us in the understanding of:

- How partners respond during the collaborative process
- How partners interpret group collective knowledge
- How partners obtain outcomes from the collaborative process via negotiation.

FEPs may have differing *perceptions* of the same input values. In order for collaboration to occur effectively, there must be an alignment of perspective. When dealing with a collaborative FEP scenario, it is entirely possible for one partner to refer to something as "large" while another may refer to the exact same source as "small".

The second application of fuzzy logic is in the approximation of one FEP's perspective of scale with their own. As responses in the form of knowledge are articulated to the group of partners, each partner is then able to "align" the response with their own internal perspective.

FEPs participating in the collaborative process are able to approximately align their responses with that of the other partners. It should also be noted that in the responses of the given partners, only one justification has been given for their response. In this chapter, we have constrained the justifications used in the play scenario to one reason. In this case, the justification of a response can be characterized as:

$$\begin{aligned} &r_m \rightarrow j_F \\ &j_F = MAX(MAX(\mu_A(x)), MAX(\mu_B(y))) \end{aligned} \tag{4.10}$$

The response r_m (where r_m is a piece of knowledge) implies a fuzzy justification j_F where j_F in our case is the linguistic term with the highest degree of membership across all inputs.

The resulting fuzzy justification is essentially the conveyance of a linguistic term to other members of the group. This in turn allows the other FEPs to evaluate the responses of other partners in relation to their own.

The justification works on the assumption that while each FEP may have a differing perception for the same inputs, all FEPs articulate their responses in the same linguistic terms (and in the same order). This allows the FEPs to measure the responses of others in relation to their own perception.

For example, if a partner p_k converses with partner p_j using a five term linguistic variable for temperature as defined in Table 4.3 with the crisp value of the temperature being 90°C.

The difference in perception can be simplified to the difference between the linguistic term of one FEP vs. another's perception. In this example, p_j would

Table 4.3. Differing perspectives on the same input

Question		Response and justification	
p_k:	"Turn the coffee brewer on?"	p_j:	"Turn it on for a medium time" "It is warm"
p_j:	"Turn the coffee brewer on?"	p_k:	"Turn it on for a long time" "It is cold"

be able to use the justification of p_k to extrapolate a model of the perception of p_k of the given problem, allowing the FEP to interpret the collective group knowledge supplied by p_k. This then allows p_j to articulate during the negotiation phase of the collaborative process in terms of the perception of inputs by p_k.

Perception does not need be an expensive process in simple scenarios. If all partners articulate their perceptions of the given inputs in the same linguistic terms, the true intention of the FEP is articulated.

The third area within the collaborative process of FEPs that can utilize fuzzy logic is in the negotiation process. At this point, all partners have evaluated the questions and made responses based upon their internal fuzzy reasoning, and all other partners have been able to form a perception of the other partners responses. The negotiation phase of the collaborative process takes the collective group knowledge accumulated during the question process and evaluates the set of outcomes based on the initial goals stated at the beginning of the process. Recall that $o_n = s(P, n(G, K^P))$. A goal g_i must be interpreted against the set of group collective knowledge related to that goal K_i:

$$\begin{aligned}
o_n &= s(P, n(G, K^P)) \\
G &= \{g_1, ..g_i\} \\
K^P &= \{{K_1}^P, .., {K_i}^P\} \\
o_n &= s(P, n(\{g_1, ..g_i\}, \{{K_1}^P, .., {K_i}^P\})) \\
o_n &= s(P, \{n(g_1, {K_1}^P), .., n(g_i, {K_i}^P)\}) \qquad (4.11)
\end{aligned}$$

The interpretation function involves setting a baseline with all group collective knowledge interpreted relative to the baseline. In practice if all partners articulate their perception using the same linguistic terms, this is a trivial operation.

Once the baseline has resulted in a set of Knowledge for the group of FEPs, this set of knowledge can be applied against each goal that the items are related to: $n(g_i, {K_i}^P)$.

In order to satisfy the outcome o_n, the collaborative function s involving all partners and the group collective knowledge interpreted against the baseline is required.

While each FEP will be articulating the group collective knowledge against the baseline, this is not enough to achieve an outcome. Negotiation involves the ability to compromise. In this chapter, we simulate negotiation through the use of an influence factor. This influence factor constraint attracts the resulting partner's decision toward that of another FEP thereby influencing their resulting opinion.

Consider four FEPs that are baristas brewing coffee. The brewing machine has a heating element used to heat water to the right brewing temperature. Using the following linguistic variable to articulate an outcome:

Input: *Temperature* = {*Cold, Warm, Brewable, Hot, Boiling*}
Output: *Make Coffee* = {*Heat, Brew, Heat Off*}

Suppose partner p_1 has had two fuzzy rules that fire based on a temperature input in the form:

IF x IS A_1 *THEN the outcome is* B_1
IF x IS A_2 *THEN the outcome is* B_2

With each rule firing for partner p_1, a final centre of gravity of 3.5 that relates to a linguistic term of *Make Coffee* is achieved. Suppose the partners in Table 4.4 have also evaluated the same rules and determined separate centers of gravity.

During the negotiation phase, we can apply an influence function to change the COG of a given partner's initial fuzzy decision based on the degree of influence the other partners have with the first partner. The influence function that is used in this chapter is simply the sum of the proportion difference between one partner's COG (obtained during the conversation process) and that of another partner:

$$i(COG) = \sum_{1-n, n \neq i} p_{nf}{}^{*}(COG_{pn} - COG_{pi}), \tag{4.12}$$

where $i(COG)$ is the influenced centre of gravity which is the sum of all influence factors multiplied by the difference between the center of gravity of partner p_n and the partner under influence p_i. FEPs using this influence function cannot influence themselves.

The following example shows how the other partners can influence partner p_1's resulting center of gravity. This in turn can potentially change a linguistic term and outcome of the collaborative process (Table 4.5).

Table 4.4. Centers of gravity for each partner

Partner	COG	Linguistic term
p_2	4.4	Heat
p_3	3.7	Brew
p_4	1.2	Heat off

Table 4.5. Influence calculation

		p_2	p_3	p_4
Influence		0.25	0.5	0.1
COG		4.4	3.7	1.2
p_1 value	3.5	0.225	0.1	−0.23
Sum influence factor	0.095			
Initial value + influence factor	3.595			

Once the negotiation phase has been completed, the resulting feedback by all FEPs on the particular outcome can then be evaluated to achieve an outcome. There are many methods for achieving an outcome. In a simple scenario, the outcome can be evaluated by a single partner (normally the leader). In more complex scenarios, a democratic system may be called for requiring the group to reach a majority position.

In the example play scenario, this outcome is achieved by applying a fuzzy decision making approach across the results of the participating FEPs. The final decision, based upon the contributions of the group is performed by the leader.

4.3 Group Decision Making Play Scenario: Software Project Tender Assessment

In the first section of this chapter, we defined what a collaborative FEP is; being either human or artificial in nature, but possessing the capability to collaborate with other FEPs as well as being able to replace any other being, regardless of their underlying nature. In Sect. 2 a formal process for collaborative interaction between human and artificial FEPs was introduced. We discussed the layers of a collaborative architecture, the collaborative process as well as a fuzzy approach to decision making within this process.

In this section, we describe a computer game play scenario where human and artificial beings may collaborate to achieve the collaborative goals of the play scenario.

4.3.1 The Scenario

A large software engineering company is involved in many development projects at any given time. Each project must be judged based on its capability, profitability and risk. The committee that oversees the selection of projects must evaluate each request for tender that the company obtains in order to determine which projects to submit a tender.

In order to determine the most suitable projects, the members of the committee each represent major organisational units within the company. In order for a project to progress to the tender stage, the committee members must find a project that is suitable for all parties.

Since this company is globally dispersed, the members of the committee rarely meet face to face, but rather perform the selection task via an electronic boardroom. In some instances, committee members have been known to use a subordinate to represent their department. In these instances, departments have been known to use an artificial committee member to represent their interests.

The selection committee is overseen by a chairperson who is responsible for managing the meeting, presenting the committee with the various requests for tender and collating the decisions made. In this scenario, the chairperson remains an impartial member of the committee.

All other members of the committee have access to information from their respective departments within the company. Sources of information usually include access to the various systems that manage different areas of the business.

The collaborative process of the electronic meeting room board members will involves six separate roles. Each role represents one of five different organisation units within the company. The additional role is that of the chairperson: the leader role in this scenario. The chairperson is responsible for obtaining tender information from various potential customers and presenting it to the rest of the group for critique. The chairperson is part of the decision making process and is responsible for the successful assessment of tenders during the meeting, however he/she does not express a personal view point on the topics under consideration.

Table 4.6 lists the six participating board members and their role.

David, as the presenter was required to provide the requests for tender to the assessment committee. He provided the tender applications given in Table 4.7 to the committee.

4.3.2 Scenario Collaborative Process

The collaborative process involved in this play scenario involves the assessment of software project tenders for suitability. By using the collaborative process

Table 4.6. FEPs involved in the play scenario

FEP	Role
David	Chairperson
Daniel	Executive
Cathy	Human resources
Ljubo	Project management
Natasha	Finance
Susan	Logistics

Table 4.7. Tender information to be presented to the committee

Customer	Lakeview city council
Tender	Tender for new property rating system
Description	The successful tender shall demonstrate a clear understanding of our Property and Rating requirements as a Local Government Organisation, being able to deliver a new system on time and on budget.
To commence	1/07/2007
Delivery By	1/07/2008
Requirements	
Skill in local govt	Minimum two analysts
Skill in rating	Minimum five analysts
Developers	Approximately 5–12 developers
Delivery	1/07/2008
Tender amount	$250,000
Market segment	Local government
Customer	Australasian Express Courier Services
Tender	Tender for new automated courier tracking system
Description	The successful tender shall provide a system by which shall allow our customers to track their deliveries in real-time via the internet, while managing the transfer, organisation and delivery of these packages.
To commence	1/01/2007
Delivery by	1/07/2007
Requirements	
Developers	Approximately 20–35 developers
Skill in supply chain systems	Minimum two analysts
Web developers	Approximately 7–18 developers
Tender amount	$1,800,000
Market segment	Logistics services
Customer	Western Australia heavy engineering
Tender	Tender for new automated rostering and timecard system
Description	The successful tender shall provide a rostering management system that can integrate with our existing timecard collection devices, as well as provide intelligent rostering for our "Fly In, Fly Out" workforces across numerous mining facilities
To commence	1/07/2007
Delivery by	30/06/2008
Requirements	
Developers	Minimum 10 developers
Business analysts	Approximately three analysts
Skills in roster design	Approximately two analysts
Time and attendance design	Approximately two analysts
Tender amount	1,100,000
Market segment	Mining industry

Table 4.8. A breakdown of the collaborative process

Collaborative step	Play scenario
Invitation	All partners have accepted the invitation to meet and discuss the latest tender requests
Attendance	All partners log into the electronic meeting room
Initiation	Once all partners have entered the electronic meeting room, the presenter starts the meeting Presenter: performs the start meeting action
Definition of goals	The presented states the goals of the electronic meeting Chairperson: "The purpose of the tender projects assessment group is to review incoming requests for tender and determine whether our company should pursue one or more of these tenders"
Presentation	The chairperson presents the collected tenders to the other committee members as defined in the formal conversation procedure detailed in Fig. 4.3
Negotiation	Once a tender has been presented, the negotiation process commences. At this point, the presenter shall establish a baseline for negotiation. Opinions are collected in terms of the baseline terminology
Conclusion	The presenter begins the conclusion phase once all negotiation has been completed. At this point, the presenter provides a summary of the collaborative process. The presenter can then present to the committee the tenders considered the best fit for their organisation. The decision is relayed to the participating partners Finally, the presenter concludes the meeting with the finish action

we can model the process involved in assessing these tenders by the committee members of the electronic meeting room. The following figure highlights how the play scenario is compatible with the collaborative process (Table 4.8).

The conversations required for the tender collaborative process must be defined prior to the construction of the play scenario. Our electronic meeting room will not be utilising "open" (Human-Like) conversations or actions, but for simplicity shall operate within a constrained conversation structure. Figure 4.6 describes this structure, questions and actions that occur every time a new tender is presented to the group of partners.

Once all tenders have been read, the presenter will then announce that Negotiation is to occur. In this process, the committee members must also exchange information amongst themselves, in order to complete their part of the assessment process.

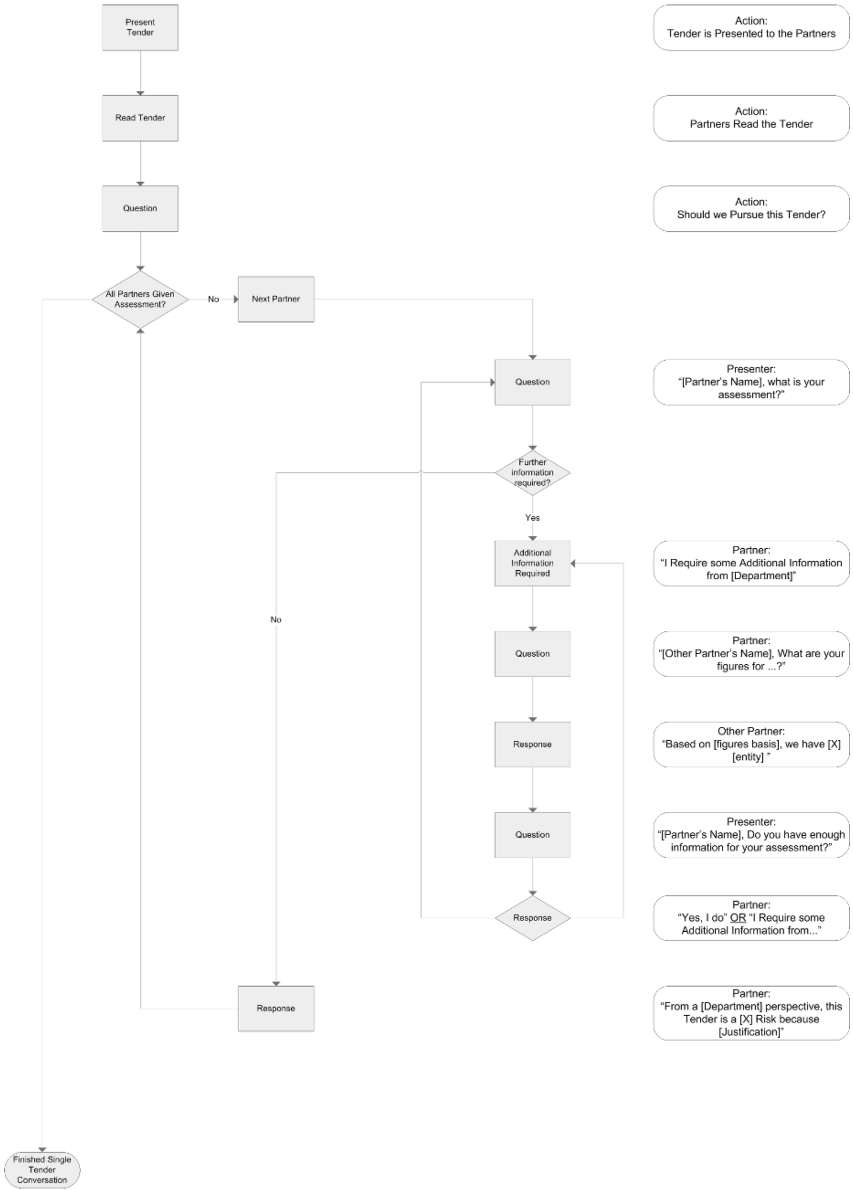

Fig. 4.6. Conversation process structure

4.3.3 Design Assumptions

For this play scenario that we shall be designing, we have made a number of assumptions about the electronic meeting room and the behaviour of the FEPs (the group of committee members) situated within it.

Firstly, the artificial beings do not possess intimate/familiar knowledge of the human that they replace. The intention of the artificial being is to replace a human, giving them the same decision capabilities within the play scenario and not to use the meeting room as a form of Turing Test (A Turing test, made famous by Allan Turing, is a test used to determine if an artificial intelligence is indistinguishable from a human being. A person presents questions to a human and artificial participant that they cannot see, and can only communicate with via a computer terminal. The person presenting questions must then choose which of the interviewees is human).

Secondly, we have limited the number of the decision makers to five FEPs.

Finally, the concept of FEP influence has been reduced to simple factors for the purposes of this the simplicity of presenting this matter in this chapter. Depending on a particular artificial being's affinity with another FEP, it is more likely that that artificial being would choose their position.

4.3.4 Architecture

The architecture of the electronic meeting room is designed around supporting the collaborative process. As such it embodies a layered collaborative architecture. Each layer is interlinked with the next providing a foundation for the collaborative process.

While the layered collaborative architecture is evident across the entire electronic meeting room computer game, the game itself consists of three parts. Firstly, the management of the electronic meeting room is handled by a central meeting room (server) component. The other two parts allow human and artificial FEPs to interact using the meeting room component (Fig. 4.7).

Each of these three parts implements the layered approach. In the design of the electronic meeting room the communication layer handles the transport of information between the electronic meeting room and the FEP interface components. The meeting room, artificial being interface and human being

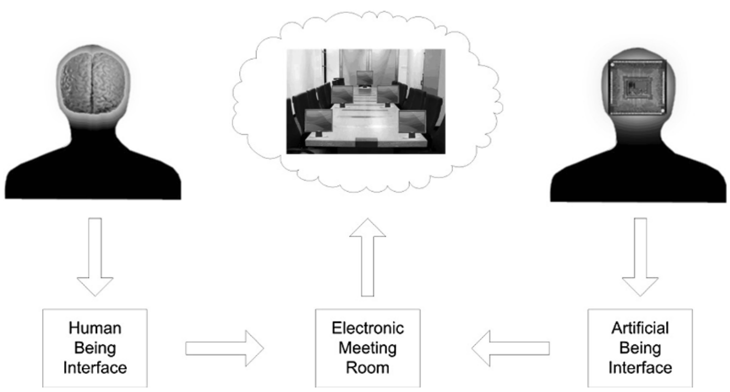

Fig. 4.7. Main software components

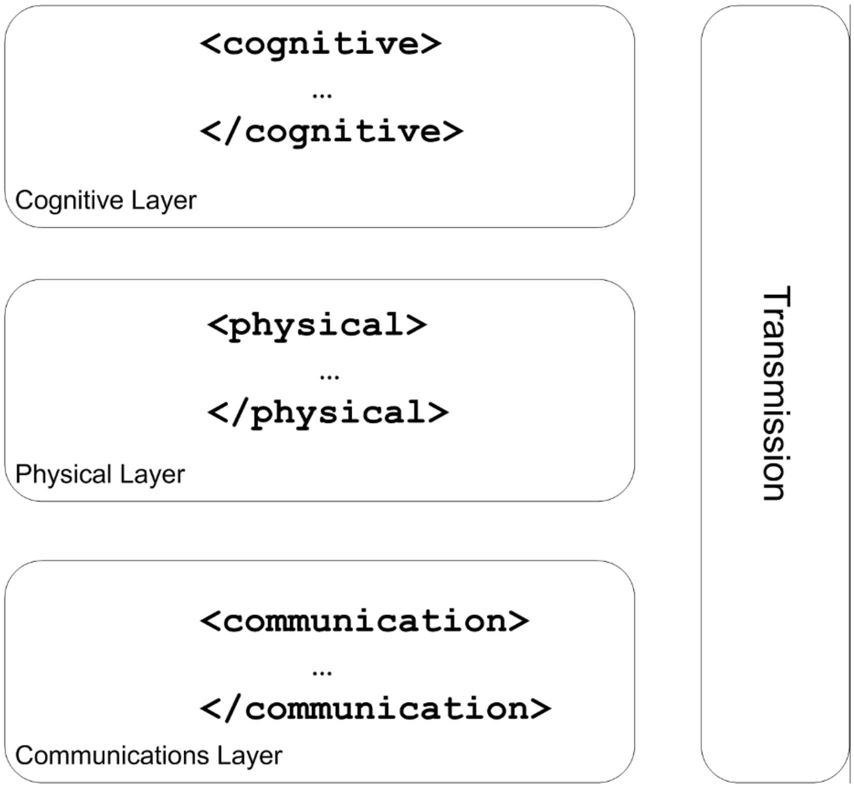

Fig. 4.8. Layered information located in transmission

interfaces operate as independent software components which may exist in a distributed form. Information is transported between each of these components in an XML structure. This allows the discrete separation of information pertaining to each layer (Fig. 4.8).

Each layer is then dealt with in a different manner. Communications layer information is used to handle software-level information such as connections and infrastructure information. The physical layer conveys information about the electronic meeting room and the manipulation of objects within the room (such as a chair, document, etc.). Finally, the cognitive layer conveys messages between each FEP so that the collaborative process may occur (Fig. 4.9).

In the play scenario that we are constructing, we need to define information about the physical layer and what affect it may have upon our tender assessment process.

For the purposes of this play scenario, we have limited the physical layer to four possible collaborative interactions (Table 4.9).

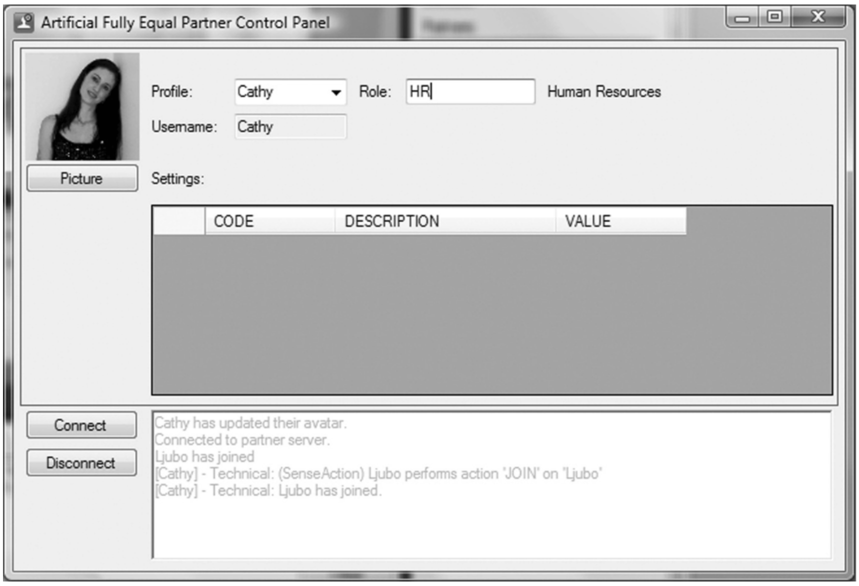

Fig. 4.9. An artificial FEP

Table 4.9. FEP roles and their actions

Action	Description	Role
Begin	Starts the meeting	Chairperson
Finish	Concludes the meeting	Chairperson
Present tender	Presents a request for tender to the other partners	Chairperson
Read tender	Reads/perceives information about a presented tender	Committee member

The cognitive layer is defined in terms of a fuzzy logic based system. For FEPs that are artificial beings, this process is used to determine the resulting decision made during the collaborative process.

4.3.5 Collaborative Process

As stated earlier in this chapter, artificial collaborative FEPs utilise fuzzy logic to determine how to respond during the collaborative process conversations. It is also used to interpret the responses of other partners and to obtain an outcome from the play scenario (the selection of potential projects to pursue based upon the requirements of each organization unit).

Each organization unit has a set of linguistic variables that are used to assess each tender. Some linguistic variables may be obtained via reading each tender's crisp values presented, however other linguistic variables require

Table 4.10. Input linguistic variables and terms for the play scenario

Role	Inputs	Outputs
Executive	Profit market segment	Corporate risk
Financial	Revenue	Financial risk
	Expenditure	
Human resources	Skills required	HR/recruitment risk
	Skill availability	
Project management	Lead time	Project management risk
	Project duration	
Logistics	Equipment outlay	Logistical risk

Table 4.11. Output linguistic variable and terms

Risk analysis	Crisp output value
Low risk	1
Medium risk	3
High risk	5

the committee member to ask another member to obtain crisp data. Each role has its own set of linguistic variables (Table 4.10).

The output decision of each partner is articulated using the various risk linguistic variables. These risk variables are then used to determine the final assessment result for each tender presented. Each of the risk variables has three terms: low, medium and high risk (based upon the perspectives of each committee member). The combined fuzzy rule table amounts to 243 assessment rules (Table 4.11).

In the next section, we discuss how the electronic meeting room's underpinning software operates within the given scenario.

4.3.6 The Software

Each human FEP that has joined the electronic meeting room perceives the room via the human interface component. They see visually themselves placed at the meeting room table along with the other partners. By default, partners only see a silhouette of all other board members in the meeting room however an image/avatar may also be nominated.

Figure 4.10 shows how Daniel has joined the meeting room. Each of the other committee members is also present and all members have nominated an image/avatar to represent themselves in the meeting room. During this meeting, Daniel is unaware whether his fellow committee members are human or artificial beings (Fig. 4.9).

From this point on, we shall discuss how the artificial FEPs behaved whilst within the play scenario. To demonstrate this, we conducted the entire play scenario with artificial FEPs.

Fig. 4.10. Human FEP software component

The artificial partners involved in the scenario used different fuzzy rules. In order to reduce the complexity of the rule set, the number of output linguistic terms presented by each FEP was reduced to three. This leads to a final fuzzy rule assessment table consisting of 243 rules. Given that each artificial partner may have a different perspective when applying the fuzzy rules to each of the submitted tenders, it can be quickly seen that there is a significant number of rules to be designed and evaluated.

The following table is a small sample of the fuzzy rules that were constructed from heuristic information provided by a number of human experts (Table 4.12).

In order to evaluate the inputs in terms of the fuzzy rules stated above, we have utilised the T-Function to determine the degree of membership each crisp value has to each of the three linguistic terms of each input. To achieve this, each membership function required values for the variables defined in (4.7). The following values were used:

1. Center b point: defined as being the value indicated by each partner for each linguistic term. (for example: Cathy defined low recruitment as being less than 5% and hence is her centre point the low recruitment membership function).
2. To determine the a and c values, we defined a "bandwidth" value for each linguistic variable. The a and c values are equal to $b - 1/2$ *bandwidth value* and $b + 1/2$ *bandwidth value*, respectively.

Table 4.12. Table of play scenario fuzzy rules

RULE	IF	HR Risk =	Projects Risk =	Financial Risk =	Logistical Risk =	Executive Risk =	Then	Suitability =
11	IF	LOW	LOW	MED	LOW	MED	Then	HIGHSUIT
12	IF	LOW	LOW	MED	LOW	HIGH	Then	HIGHSUIT
13	IF	LOW	LOW	MED	MED	LOW	Then	HIGHSUIT
14	IF	LOW	LOW	MED	MED	MED	Then	SUITABLE
15	IF	LOW	LOW	MED	MED	HIGH	Then	SUITABLE
16	IF	LOW	LOW	MED	HIGH	LOW	Then	HIGHSUIT
17	IF	LOW	LOW	MED	HIGH	MED	Then	SUITABLE
18	IF	LOW	LOW	MED	HIGH	HIGH	Then	UNSUITABLE
19	IF	LOW	LOW	HIGH	LOW	LOW	Then	HIGHSUIT
20	IF	LOW	LOW	HIGH	LOW	MED	Then	HIGHSUIT
21	IF	LOW	LOW	HIGH	LOW	HIGH	Then	HIGHSUIT
22	IF	LOW	LOW	HIGH	MED	LOW	Then	HIGHSUIT
23	IF	LOW	LOW	HIGH	MED	MED	Then	SUITABLE
24	IF	LOW	LOW	HIGH	MED	HIGH	Then	UNSUITABLE
25	IF	LOW	LOW	HIGH	HIGH	LOW	Then	HIGHSUIT
26	IF	LOW	LOW	HIGH	HIGH	MED	Then	UNSUITABLE
27	IF	LOW	LOW	HIGH	HIGH	HIGH	Then	UNSUITABLE
28	IF	LOW	MED	LOW	LOW	LOW	Then	HIGHSUIT
29	IF	LOW	MED	LOW	LOW	MED	Then	HIGHSUIT
30	IF	LOW	MED	LOW	LOW	HIGH	Then	HIGHSUIT

The following sample demonstrates part of the collaborative process in action:

David `Should we pursue this tender?`
(Action) `A new tender is being presented`

(Presenting Tender for New Automated Rostering and Timecard System)

(Action) `Cathy performs action 'READ' on 'TENDER'`
(Action) `Ljubo performs action 'READ' on 'TENDER'`
David `Cathy, what is your assessment?`
Cathy `I require additional information from Project Management`
Cathy `Ljubo, what are your figures for Available Skills?`
Ljubo `Based on Available Skills, we have 49 Percent Availability`
David `Cathy, Do you have enough information for your assessment?`
Cathy `Yes I Do`
David `Cathy, what is your assessment?`
Cathy `From a Human Resources perspective, this Tender is a Low Risk because of Percentage Recruitment Required and Available Skills`

Table 4.13. Linguistic variables utilised by human resources artificial partner

Linguistic variable	linguistic term	Crisp value
Skill availability (%)	Low	25
	Medium	50
Bandwidth = 50	High	75
Recruitment	Low	5
Required (%)	Medium	10
Bandwidth = 10	High	15

Table 4.14. Fuzzy table used by the human resources artificial partner

IF	Skill availability =	AND	Recruitment Required =	THEN	HR Risk =
IF	HIGH	AND	LOW	THEN	LOW
IF	HIGH	AND	MED	THEN	LOW
IF	HIGH	AND	HIGH	THEN	HIGH
IF	MED	AND	LOW	THEN	MED
IF	MED	AND	MED	THEN	MED
IF	MED	AND	HIGH	THEN	HIGH
IF	LOW	AND	LOW	THEN	HIGH
IF	LOW	AND	MED	THEN	HIGH
IF	LOW	AND	HIGH	THEN	HIGH

When Cathy is assessing the merits of this particular tender, as an artificial being, the information in Table 4.13 was used.

The artificial partner representing the Human Resources department of this company applies its assessment of the tender based upon availability of resources required (i.e. Employees that will be available to work on this project) as well as any recruitment effort required to offset any shortfall in skills. To achieve this, the artificial partner requires information from the Tender, as well as their Project Management counterpart. Once this information is collected, the following table of fuzzy rules is applied to achieve an assessment in terms of human resource requirements (Table 4.14).

The resulting application of the equations specified in (4.7) resulted in the following results being recorded and then used by the artificial partner to respond with their assessment of the tender:

(Cathy - Technical): `Fuzzy Evaluation Called`

```
BEGIN - DoFuzzyProcess()
    Result Sum Area: 4.8456
    Result Sum BPointArea: 9.252
    Centre of Gravity: 1.909
```

`FINISH - DoFuzzyProcess() result:` **HRRISK is LOW**

Table 4.15. Conclusion phase stating the final outcomes

Conclusions given	Centre of gravity (Equation (4.8), as applied to rules shown by Table 4.14)
Based on your contributions, the tender "Tender for New Property Rating System" is SUITABLE for our business to pursue	2.9365
Based on your contributions, the tender "Tender for New Automated Courier Tracking System" is UNSUITABLE for our business to pursue	1.8148
Based on your contributions, the tender "Tender for New Automated Rostering and Timecard System' is SUITABLE for our business to pursue	2.9365

Conclusion

The final part of the collaborative process is the conclusion phase. In the electronic meeting room, the final decision based on the feedback provided by all partners is to be made by the Chairperson. The following process is used to determine a final outcome of the electronic meeting room:

1. An average COG is determined for each tender.
2. Since the outcome is to obtain a tender within the suitable to highly suitable range of assessments, the averages for each tender are then evaluated using the membership functions for suitable and highly suitable linguistic terms. Recall that the b Point for Suitable and Highly Suitable are 3 and 5 respectively with a bandwidth of 3.
3. The resulting centre of gravity across the average and good linguistic terms determines the final outcome value.
4. The final assessment of each tender as determined by the group are as follows:

By following through the collaborative processes within the electronic meeting room play scenario, we have been able to ascertain that only two of the presented tenders were suitable for our business to pursue.

This scenario demonstrates the layered approach to design and development of computer game-based collaborative decision-making play scenarios. Figure 4.11 shows how the tender evaluation system consists of three distinct layers. The communications layer, implemented using technologies such as XML and service-based communication. The physical layer defining the objects and actions available to the committee members, and finally the cognitive layer, consisting of the cognitive process as well as interfaces that permit the communication between human and artificial beings situated within the tender evaluation system.

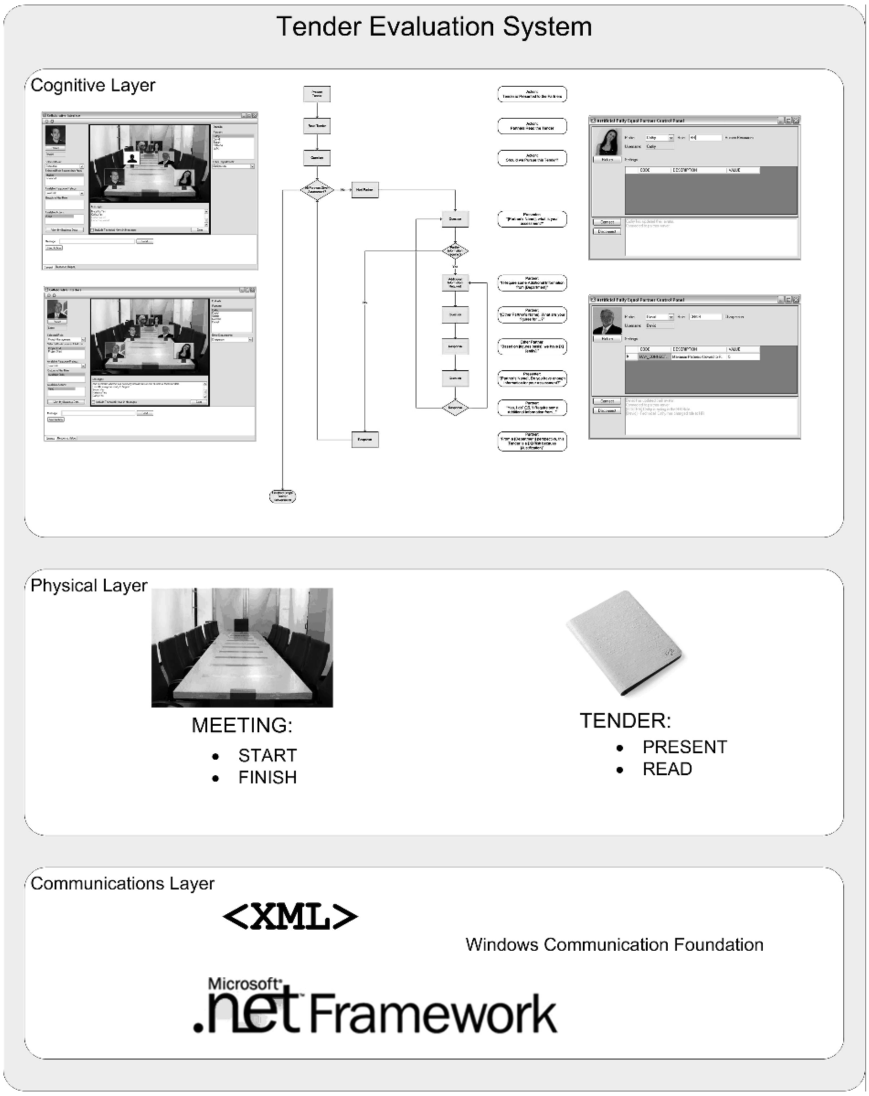

Fig. 4.11. Layered architecture of the tender evaluation system

4.4 Concluding Remarks

In this chapter we have explored the concept of human and artificial beings as FEPs in collaborative decision making situations. Collaborative FEPs are fully replaceable or interchangeable with any other FEP and are not necessarily aware that the other partners are human or artificial beings.

We have presented a method for dealing with collaboration between FEPs by using a structured collaborative process. Within this process, we have shown how fuzzy logic can be applied to achieve collaborative outcomes and have demonstrated the application of these concepts through a simple play scenario.

This collaborative scenario also demonstrates that interaction amongst human and artificial beings as FEPs is possible in many fields, which broadens the application of this application for potential use in social interactions.

4.4.1 Additional Considerations

As discussed earlier, for simplicity the electronic meeting room play scenario had its scope constrained in a number of areas. These areas provide opportunity to consider additional improvements to the play scenario. Architecturally, the system maintains fuzzy rules, scenarios, roles and settings via a generic database structure, allowing it to be easily extended in this fashion.

Firstly, the play scenario can be extended to a support a greater number of participants within the collaborative process.

The number of inputs into the play scenario may be extended to consider additional areas of consideration for the FEPs.

Changes can be made to the decision-making processes being used within the artificial FEPs to include memory in the fuzzy decision making process. It would also be possible to completely replace the fuzzy decision making components with a different intelligent decision-making methodology that would be used within the collaborative process.

There are also many architectural design features (both implicit and explicit) that support FEPs in collaborative computer games. Some of these desirable features that support a computer game as a collaborative FEP element were identified by Thomas and Vlacic (2003). The result of this work was determining key software design attributes necessary to facilitate effective collaboration within computer games. These attributes are an effective guide when designing collaborative computer games from an architectural perspective.

While a collaborative computer game is a vehicle for intelligent, cognitive game play, it is also our research platform. As such, it requires certain attributes and interfaces necessary for the study of collaborative beings. The following architectural properties support a cooperative game platform that facilitates collaborative FEPs play scenarios:

Exogenous events. (Hanks et al., 1993) in order to emulate the adaptive, collaborative and cognitive abilities of real world (embodied) beings within a collaborative computer game, we must introduce into play scenarios an element of unexpected change to the state of play (or, as is the case with experimentation, *manufacture* these unplanned events if required).

Causal structure. A complex causal structure is necessary to imitate the complex cause and effect actions and reactions of real-world scenarios. Our approach provides a causality structure necessary to exhibit complex collaborative (and cognitive) abilities in the FEPs situated within the game. Causality is realized through rules defined by the physical layer, as well as more complex rules determined by the cognitive layer.

A concept of time. The collaborative computer game and the FEPs situated within it must be able to operate within a linear time environment. For the purposes of the game, a play scenario defined by the physical layer may have a very simple time structure (based on a sequence of events and/or triggers) or a more complex real-time system where effective collaboration may require the ability to respond within a finite time span.

Support for experimentation. having the ability to control the conditions within the game, thus allowing for repeatable, quantifiable play scenarios (Vincent et al., 2000).

A well-defined interface between the collaborative computer game and beings that are situated within it is necessary to support true autonomy of the FEPs within the game and encourages collaborative behavior.

In addition to these desirable features that support a collaborative computer game were also a number of practical considerations identified when selecting or constructing a collaborative computer game. While not directly related to supporting a layered architecture approach, practical features will affect the embodiment of a collaborative computer game:

The availability and cost of infrastructure and development tools required;

The learning curve required in order to be completely familiar with the underlying infrastructure used to construct human and artificial software interfaces;

Environmental complexity was also identified as an important factor in creating an effective collaborative computer game. This becomes more of an issue for the scalability of complex elements (especially the causal structure), as we move from simpler play scenarios to the more complex, introducing more sophisticated elements to the cognitive layer.

Documentation (or lack thereof) is a strong factor for and against a particular tool or infrastructure. When selecting the necessary tools to construct a collaborative computer game, availability of adequate reference material and support structure is imperative so as not to detract from constructing an effective realization of the concept with distracting technical issues.

4.4.2 Other Applications for Collaborative Decision Making

In this chapter we have discussed collaborative FEPs in the context of computer games, demonstrating such a system in action by way of the electronic meeting room play scenario. While the concept of collaborative FEPs is compelling in today's software industry, where intelligent artificial players interact and collaborate effectively with human players, there are many other fields of endeavour that can benefit from this concept.

As businesses look for more ways to gain an edge over their competitors, training and recruitment form a major part of the work done by Human Resource departments in large businesses. The cost of training alone for a large organisation can be staggering. We see collaborative FEPs being used as a tool in self guided training, group training and recruitment. An organisation may develop a training course that is taught by an artificial FEP, or group learning activities where humans and artificial beings collaborate to practice teamwork, acting in particular roles where one or more humans may require training. It could also be used as a tool in the recruitment process to gauge a recruit's responses when confronted with a team-based scenario.

While we have concentrated on a linguistic form of communication in our exploration of the collaborative process, there are many non verbal methods of conveying ideas and intentions to other FEPs.

One of the biggest challenges in research and development is intelligent automated transportation. One of the challenges facing researchers in this field is how intelligent transport systems can operate *within* our current system rather than being in its own separate/contained transport network.

By using a collaborative FEP approach, it is possible to integrate human drivers and intelligent automated transport systems are FEPs participating in the collaborative process of moving from one place to another efficiently and safely. Artificial beings in this category of transport system would be able to communicate to each other, while sensors are able to detect the intentions of human drivers (such as a turning indicator) allowing artificial drivers to collaborate with the other vehicles on the road.

Socially-oriented computer games are another area where collaborative human and artificial beings acting as FEPs find potential application. This application may be of potential use in the fields of clinical psychology and behavioural studies. There are many open questions about how application of this technology may be used as a "safe" environment to assist those in need of specialised social/behavioural assistance. It is upon us, as collaborative beings to investigate with our colleagues in these disciplines and examine potential application in this field as collaborative fully equal partners.

References

Beinisch Y, Paunov C, Vickery G, Vincent, SW (2005): Digital Broadband Content: The online computer and video game industry Organisation for Economic Co-operation and Development Report (OECD)

Hanks S, Pollack M, Cohen P (1993): Benchmarks, Testbeds, Controlled Experimentation, and the Design of Agent Architectures AI Magazine, AAAI Press, 14:17–42

Jennings NR, Wooldridge M (1995): Intelligent Agents: Theory and Practice Knowledge Engineering Review, 10

Laird JE (2001) Using a Computer Game to Develop Advanced AI IEEE Computer, 34:70–75

Magerko B, Laird JE, Assanie M, Kerfoot A, Stokes D (2004): AI characters and directors for interactive computer games, Proceedings of the 2004 Innovative Applications of Artificial Intelligence Conference

Passino KM, Yurkovich S (1998): Fuzzy Control, Addison-Wesley, Reading, MA
Riedl M, Saretto CJ, Young MR (2003): Managing interaction between users and agents in a multiagent storytelling environment, Proceedings of the Second International Conference on Autonomous Agents and Multi-Agent Systems
Thomas D, Vlacic L (2003): Selecting an environment for cooperative autonomous robot research. In: Hyungsuck Cho JK, Lee J (ed.), Intelligent Robots: Vision, Learning and Interaction. KAIST Press, pp. 187–198
Thomas D, Vlacic L (2005): TeamMATE: Computer Game Environment for Collaborative and Social Interaction IEEE Workshop on Advanced Robotics and its Social Impacts (ARSO'05)
Vincent R, Horling B, Lesser V (2000): Experiences in Simulating Multi-Agent Systems Using TAEMS, The Fourth International Conference on MultiAgent Systems (ICMAS 2000), AAAI
Yan J, Ryan M, Power J (1994): Using Fuzzy Logic, Prentice-Hall, Englewood Cliffs, NJ