Applying fuzzy logic to model user preferences on multimedia sessions *

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Resumen

This work is enclosed inside a more general task which is the proposal of a new approach based on intelligent agents for the initiation, control and adaptation of a multimedia session. The overall contribution of this work is an intent to fill the gap between what the different users implied consider as their preferred multimedia session characteristics and the actual multimedia session established and maintained. Particularly, we focus here on specifying user preferences on media by using fuzzy logic. This preferences will guide the process of scoring, from the user point of view, any possible multimedia session configuration. In turn, this will allow for a further negotiation on possible session to establish between communicating peers.

1 Introduction

Multi-agent systems are called to play an important role in the new information systems coming into the third millennium. The kind of applications we refer to will have new features like, for example, they will be user-centric, adaptable to changing conditions and context aware [2]. Moreover, they will have to be able to execute in more and more heterogeneous environments both in terms of data transport telecommunication networks and devices connected to that networks and hosting the applications. Examples of such kind of systems are [9, 15]. This examples emphasize two simple but powerful ideas: the first idea is that computers should be present in the typical daily tasks at the work place and the second one is that applications should tightly adapt to the user.

This article deals with the *user-centric* feature. It shows our approach to allow an user to specify preferences on the media used for potential multimedia sessions which could be established with the rest of users of our application. The general task we are involved in is the management of a complete multimedia session between applications built by using intelligent agents, inside of a system we are currently developing in our research group. This is basically a multi-agent system compound by agents which act on behalf of the user (i.e. user agents) and the typical user is either a pupil or a teacher of our Computer Science Faculty. The assistance given by these agents is summarized by the following main features: (1) facilities for the pupil to obtain appointments with professors to make inquiries, (2) facilities for discussion and scientific collaboration between researchers and pupils, (3) facilities for concrete collaborations between professors and pupils and (4) the most important issue we are pursuing: to augment professors availability by providing access to them at any time and any place of the Faculty through the use of a variety of heterogeneous devices such a personal computer, a laptop or a PDA (Personal Digital Assistant).

The rest of the article is organized as follows: in section 2 we introduce the issue of the negotiation of the multimedia session between two peers from a multi-agent perspective. In section 3 our fuzzy modeling [1] approach for allowing an user to express his interests of the different media involved in a multimedia session is explained. Finally, section 4 gathers all conclusions extracted from the work and points some future works.

2 The negotiation process

When a multimedia session is going to be established between two or more users, each user will access the session with a concrete terminal. Each terminal in

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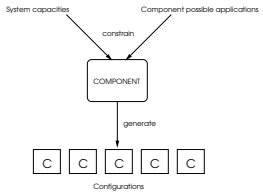


Figura 1: Obtaining configurations from the components and system capacities

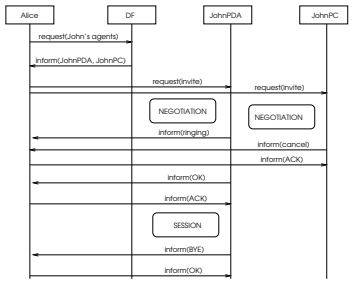


Figura 2: Session establishment and negotiation between an initiator and two possible peers.

turn will be characterized by the hardware and software resources it needs. Resources define the limitations about what, and what not, can be visualized, printed and captured with the terminal (or device). **System capacities** are defined as all the features offered and limited by the system. Moreover, when the session is going to be established, the different media that will be used have to be specified. **Session Components** are the different communication elements that will be used. This paper considers only audio and video components. A component is defined by (a) the functionality it provides and (b) one of more ways to provide the functionality. Each one of the different ways of providing functionality is named a **configuration**. The relation between these three concepts is represented at figure 1. The negotiation process generates two different kinds of configurations: potential and real configurations. A potential configuration is the set of possible configurations which can be adopted by the system. A real configuration is a concrete instantiation of one of the potential ones.

When designing the negotiation mechanism form session establishment, two different problems must be solved in turn: (1) the design of a mechanism by means of which the user can specify preferences on audio and video and (2) the definition of a protocol and negotiation strategy to be used by the agents implied in the determination of the real configuration the session will have meanwhile reaching an acceptable satisfaction level for these agents. This article is devoted to explain our approach to allow an user specifying preferences on audio and video by means of fuzzy logic (i.e., the first problem). However, the negotiation mechanism will be introduced now to make our proposal more understandable.

To better locate the negotiation process [11, 12] we will use a sequence diagram, like the one appearing at figure 2. In that figure, the user agent of Alice, let it be denoted as `Alice`, wants to establish a multimedia session with John through one of his user agents. At the moment of initiating the interaction, John is connected to the system by `JohnPDA` and `JohnPC`, corresponding to an user agent at a PDA and other user agent running at its desktop personal computer, respectively. The first interaction is initiated by `Alice`, requesting the directory facilitator (DF) the addresses of John's agents. After that, `Alice` sends an INVITE command to `JohnPDA` and `JohnPC`. This command, and the rest of commands of the interaction, is one of the possible commands of the SIP [10] Internet protocol, used for session management. Once this is done, the negotiation process starts. This task can be seen as a search process [3], in which the three agents move from point to point of the search space until `Alice` meets with one of the other two at one of these points. Obviously, each point is a possible agreement and it will be compound of the description of the multimedia session the users will maintain for communication and an utility value each agent will obtain on reaching the agreement at the specific point. But, how to score each possible point? This score will depend on user preferences on the media implied in the session. We will use a fuzzy inference system (FIS) to model this issue and compound with this model the ultimate utility function needed by each agent to enable the negotiation. Once `Alice` decides that it wants to establish the session with `JohnPDA`, the session is normally established and, eventually, terminated.

3 Modeling user preferences with fuzzy logic

Consider the user John. In principle, John is able of establishing a session with any other user of the system. Generically, John will have **generic preferences** on using the system. A preference of this kind could be, for example, the window look-and-feel style he likes for the application. He can also be connected to the system by a number of different devices, a PDA, a laptop or a personal computer, running a FIPA platform like JADE or LEAP. For each kind of device he will also have **device preferences**. For example, two different sound codecs would be preferred in a PDA and a Desktop Computer. Finally, communication with the

Parameter	Values	Explanation
AUDCOD	PCM, G711-u, G722, GSM	Audio codec
VIDCOD	MJPEG, H.263	Video codec
FSIZE	CIF, QCIF, 160x128	Size of video frames
FPS	$\{0, \ldots, 12\}$	Frames by second sent
QFVIDEO	[0,100]	Quantify f. of video codec

Tabla 1: Parameters considered as interesting topics for the user

other users will be done by using concrete applications like, for example, videoconferencing, chat, e-mail and so on. He will also have **media preferences** for that. This paper focuses only on media preferences.

3.1 Audio and video user preferences

Once the media are fixed to audio and video, the adaptation level we have worked on has into account the five parameters appearing at table 1. Obviously, we can make a correspondence between each one of this parameters and a topic over which the user could express his interest about. In fact, the user will express his preferences over audio and video by assigning a number in $[0, 1]$ for each topic of table 1. The higher the number, the higher his interest.

The link between specification of preferences by the user and the negotiation phase is the utility function used by each agent in the negotiation. This function will provide a valuation of utility in $[0, 1]$ for each real configuration that could be adopted as a possible multimedia session set up.

Given a real configuration, the agent needs to calculate an acceptance degree for it (**utility**), depending on what the user considers as interesting configurations. For this aim the agent must take into account the interest of the user about each configuration parameter. For example, if the interest of the user about the audio codec is high, then a PCM video codec would be the most suitable option (this is the best codec available), at least taking into account this particular parameter. Besides, the user will have certain preferences about the remaining parameters and they all must contribute to the calculus of the global utility for the real configuration. In order to model how the user interest about each one of the parameters contributes to the global utility of a given real configuration, we have used **fuzzy inference systems** (FIS) [14, 6].

3.2 Related work

But before we get inside the details we will point to some related work we have found in the literature. If we look at the problem from a high abstraction level, what we have to find is a function which evaluates different combinations of values for a number of attributes. Techniques for evaluating different combinations of attribute values can be drawn from the domain of Multi-attribute Utility Theory [5, 8]. One of the most well known application of these kind of techniques is the evaluation of a given product in an electronic shopping environment. For example, in [13] an adaptive recommender system is proposed. It supports the user in finding interesting products in an electronic product catalog. This system gives a measure of how well the catalog entries match the user preferences taking into account weights representing the relative importance between attributes and functions quantifying their respective utility. Finally, the evaluation of each product is obtained combining the partial utilities by means of an aggregation function. Another example can be found in [7], where a multiagent trading environment is proposed to support electronic trading. The buyer expresses his preferences in terms of *don't care, wont accept, must have*, or even a percentage of interest. A purchasing adviser agent analyzes the buyer's requirements and selects the most suitable product from a list designed by a merchant agent ins a similar manner to that of the previous example. However the most interesting issue there is the way in which the merchant agent generates the list of suitable products. It uses fuzzy logic to match the user preferences with every product. If a product exhibits a feature that exactly matches the buyer's requirements for that feature, then the product is given a score equal to the weight the buyer has attached to that feature. If not, fuzzy rules are applied to enable the product to score some fraction of the weight. Another related example can be found in [4] in which user preferences are expressed in terms of linguistic labels as: *like, interest, indifference* and *dislike*.

3.3 Fuzzy inference systems

A FIS is a computational tool to describe systems by means of its input-output relations. Its foundations can be found in fuzzy sets and fuzzy reasoning theory. It structures the knowledge using IF-THEN rules in terms of fuzzy quantities.

Three main elements can be distinguished in a FIS. The first is the **rules base**. For example, a FIS involving two inputs and one output usually has the form:

Rule 1: IF x is A_1 AND y is B_1 THEN z is C_1
ALSO
Rule 2: IF x is A_2 AND y is B_2 THEN z is C_2,
ALSO
...
ALSO
Rule r: IF x is A_r AND y is B_r THEN z is C_r

where $x \in X$ and $y \in Y$ are the input variables, $z \in Z$ is the output one and A_i, B_i and C_i with $i = 1, \ldots, r$, are fuzzy sets. Since these fuzzy amounts can have an associated linguistic term [16], the second element of

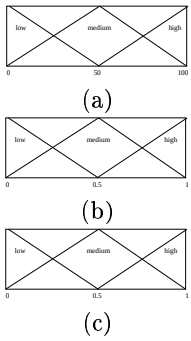


Figura 3: The dictionary: (a) for video quality factor, (b) for user interest; (c) for utility.

a FIS is a **dictionary** that associates each linguistic term with a fuzzy set. For example, each fuzzy set in the previous rules base could be associated to a linguistic label as *high*, *low*, etc.. So the dictionary links each linguistic term with its definition as fuzzy set. In figure 3, the dictionary for video quality factor, user interest, and global utility fuzzy variables can be found.

Finally, the third element is a **fuzzy reasoning method (FRM)** by means of which an output is inferred starting from a given input. Basically, a concrete FRM explains how to use a given input and the rule base to produce an output.

For our problem five FISs, F_i being $i = 1, \ldots, 5$, have been designed. F_i models how the user interest in parameter i (corresponding to the i-th row of table 1) affects to the global utility of a given real configuration. Therefore, the final utility is obtained by aggregating (fuzzy union) the fuzzy outputs of the five FISs. However, since this output is a fuzzy value and we want to obtain a real one, a *defuzzification* step must be done. We use for that the so called *center of area* (COA) defuzzification method.

3.4 A FIS for the Audio Codec

An an example of using a FIS for a discrete topic, the following is the FIS FIS_1 that models the contribution to utility from the audio codec, and user interest on the topic:

Rule 1: IF $interest_{audcod}$ is Low AND $conf_{audcod}$ is GSM
THEN $utility$ is $Medium$
ALSO
Rule 2: IF $interest_{audcod}$ is Low AND $conf_{audcod}$ is $G711$
THEN $utility$ is $Medium$
ALSO
Rule 3: IF $interest_{audcod}$ is Low AND $conf_{audcod}$ is $G712$
THEN $utility$ is $Medium$
ALSO
Rule 4: IF $interest_{audcod}$ is Low AND $conf_{audcod}$ is PCM
THEN $utility$ is $Medium$
ALSO
Rule 5: IF $interest_{audcod}$ is $Medium$ AND $conf_{audcod}$ is GSM
THEN $utility$ is Low
ALSO
Rule 6: IF $interest_{audcod}$ is $Medium$ AND $conf_{audcod}$ is $G711$
THEN $utility$ is $Medium$
ALSO
Rule 7: IF $interest_{audcod}$ is $Medium$ AND $conf_{audcod}$ is $G712$
THEN $utility$ is $Medium$
ALSO
Rule 8: IF $interest_{audcod}$ is $Medium$ AND $conf_{audcod}$ is PCM
THEN $utility$ is $Medium$
ALSO
Rule 9: IF $interest_{audcod}$ is $High$ AND $conf_{audcod}$ is GSM
THEN $utility$ is Low
ALSO
Rule 10: IF $interest_{audcod}$ is $High$ AND $conf_{audcod}$ is $G711$
THEN $utility$ is Low
ALSO
Rule 11: IF $interest_{audcod}$ is $High$ AND $conf_{audcod}$ is $G712$
THEN $utility$ is $Medium$
ALSO
Rule 12: IF $interest_{audcod}$ is $High$ AND $conf_{audcod}$ is PCM
THEN $utility$ is $High$

where $interest_{audcod}$ refers to the real interest the user has on the audio codec, $conf_{audcod}$ refers to the particular audio codec used and $utility$ is the contribution of the topic (i.e. audio codec) to the global utility. The first four rules express that, when the user in not interested in the audio codec (i.e. the user does not mind if the audio sounds good or bad), the utility of the given configuration will be medium in such a way that it does not interfere a possible particular preference of the other side. Rule labeled as $Rule_5$ express that the higher the interest in the audio codec, the lower the utility of a configuration with GSM (as GSM is the worst audio codec that can be used at the system). Finally, rule number 12 express that the most interesting audio codec is PCM.

We have considered three linguistic labels to express the user interest about a configuration parameter: *Low, Medium* and *High.* Their associated fuzzy sets are illustrated in figure 3(b). The partition expressing the different levels of utility is shown in figure 3(c). Finally we must remark that the values of the parameter corresponding to the audio codec are discrete ones but they can be managed as singleton fuzzy sets when they are involved in fuzzy rules.

3.5 A FIS for the video quality factor

As an example of using a FIS for a continuous topic, the following FIS_5 is the one concerning the quality factor for the video codec, which takes values in

$[0, 100]$:

Rule 1: IF $interest_{qfvideo}$ is Low AND $conf_{qfvideo}$ is $High$
THEN $utility$ is $Medium$
ALSO
Rule 2: IF $interest_{qfvideo}$ is Low AND $conf_{qfvideo}$ is $Medium$
THEN $utility$ is $Medium$
ALSO
Rule 3: IF $interest_{qfvideo}$ is Low AND $conf_{qfvido}$ is Low
THEN $utility$ is $Medium$
ALSO
Rule 4: IF $interest_{qfvideo}$ is $Medium$ AND $conf_{qfvideo}$ is $High$
THEN $utility$ is $Medium$
ALSO
Rule 5: IF $interest_{qfvideo}$ is $Medium$ AND $conf_{qfvideo}$ is $Medium$
THEN $utility$ is $Medium$
ALSO
Rule 6: IF $interest_{qfvideo}$ is $Medium$ AND $conf_{qfvideo}$ is Low
THEN $utility$ is Low
ALSO
Rule 7: IF $interest_{qfvideo}$ is $High$ AND $conf_{qfvideo}$ is $High$
THEN $utility$ is $High$
ALSO
Rule 8: IF $interest_{qfvideo}$ is $High$ AND $conf_{qfvideo}$ is $Medium$
THEN $utility$ is $Medium$
ALSO
Rule 9: IF $interest_{qfvideo}$ is $High$ AND $conf_{qfvideo}$ is Low
THEN $utility$ is Low

where $interest_{qfvideo}$ refers to the real interest the user has on the quality factor for video, $conf_{qfvideo}$ refers to the real value for the quality factor and $utility$ is the contribution of the topic (i.e. quality factor for video) to the global utility. The linguistic terms that model the domain of quality factor for video, are shown in figure 3(a). They provide a concrete meaning to the rules in FIS_5. The first three rules lead to a medium utility in order to not interfere with the interest of the other peer for the same parameter. The rest of the rules express that the higher the interest in the quality factor and the higher the quality factor, the higher the utility of the configuration.

3.6 Fuzzy inference systems at work

Figure 4 shows the defuzzified outputs (i.e. real values) of FIS_1. It illustrates the utility variation of a real configuration taking into account only the interest of the user on the audio codec topic. The solid line represents this utility given that the current real configuration has a value of GSM for the audio codec. For low values of interest from the user on the audio codec, the only rules of FIS_1 that fire are $Rule_1$ and $Rule_5$. Hence, when the interest is low then the utility takes middle values but when the interest reach 0.5 value, then the utility decreases to 0.2. At this point the only fired rules are $Rule_5$ and $Rule_9$ maintaining the utility in low level. The slight increment at point 0.5 is due to greater firing strength achieved when the two antecedents of each rule are fulfilled with a 0.5 degree. The dotted line represents the utility given that the current value for the audio codec is PCM. As it is expressed in FIS_1 it can be observed how the utility grows from a medium value to 1 (the higher one) as user interest in the audio codec increases. When the audio codec is G712 (a low-medium quality codec), if user interest in the topic is low or medium then it

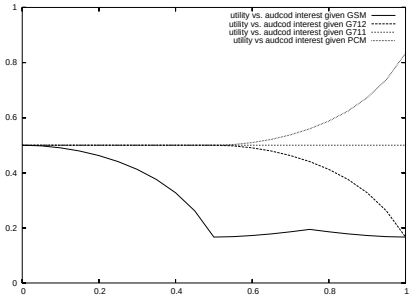
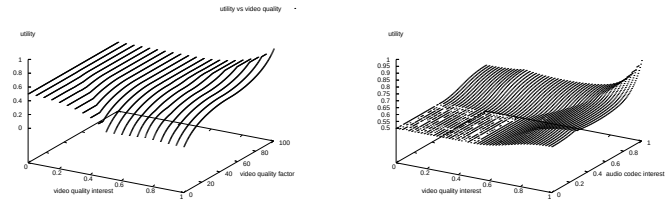


Figura 4: FIS_1 outputs (i.e. partial utility) depending on the audio codec and user interest (x axis) on the topic



(a) (b)

Figura 5: (a) FIS_5 outputs (i.e. partial utility) depending on the quality factor and user interest on the topic, (b) Global utility given that quality factor is 100 and audio codec is GSM, depending on user interest in each topic.

is considered pretty suitable. However, its utility decreases as user interest in the topic grows. Finally, we can see that a G711 configuration has a 0.5 utility whatever the user interest could be.

Graph (a) at figure 5 shows the output of FIS_5 once it is defuzzified. It shows how the utility of a given configuration changes when user interest about the quality factor topic is taken in mind. When the interest in this parameter is low, any value for the quality factor is assigned a medium utility value. As the interest grows the utility of real configurations having a low quality factor decreases to 0. Finally, when user interest in this parameter is high, multimedia session actual configurations with greater values for the quality factor are assigned the highest utility values (1).

Now that it have been shown the relation between utility and interest for a discrete domain, the audio codec, and for a continuous one, the quality factor, let us illustrate how the partial utilities are aggregated to infer the global utility. We have to remark that there is one FIS for each of the five configuration parameters and their outputs must be aggregated to infer the global

utility but, to simplify, in this paper we only consider FIS_1 and FIS_5 tied to the audio codec and quality factor, respectively. Graph (b) at figure 5 shows the variation of the global utility in relation to the variation of the two topics, given a configuration with a PCM audio codec (the best one) and a quality factor of 100 (the highest value). When interest in both parameters is low this configuration is given a medium value of utility. In this way if the other user likes this configuration then the agent of the first user should accept it, since its user does not care about the value of these two parameters. Besides, as user interest on quality factor grows, the utility also grows, since 100 is the highest value for the quality factor. Similarly, as user interest on audio increases then the utility of the given configuration improves because PCM is the best available audio codec. Finally, it can be observed that this configuration is assigned the higher level of utility (1) when then interest in each one of the two parameters is high.

4 Conclusions and future trends

In this paper, the use of fuzzy modeling to allow an user to express his preferences on the different media involved in a multimedia session is introduced. We have demonstrated the usefulness of fuzzy logic to model user interests on the topics which participate in the description of an audio and video session. With a fuzzy inference system, we can assign utility values for multimedia configurations which perfectly reflect what the user consider as important for a session. Utility values are necessary to enable negotiation between agents to decide which is the most convenient multimedia configuration for both.

Future works include considering not only media preferences but also device and generic preferences following the same approach as the one introduced in this paper.

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