From a User-created Corpus of Virtual Agent's Non-verbal Behavior to a Computational Model of Interpersonal Attitudes

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Laboratoire Traitement et Communication de l'Information, CNRS-LTCI
Télécom Paristech - 37/39 rue Dareau
75014 Paris FRANCE
{brian.ravenet,magalie.ochs,catherine.pelachaud}@telecom-paristech.fr

Abstract. Human's non-verbal behavior may convey different meanings. They can reflect one's emotional states, communicative intentions but also his social relations with someone else, *i.e.* his interpersonal attitude. In order to determine the non-verbal behavior that a virtual agent should display to convey particular interpersonal attitudes, we have collected a corpus of virtual agent's non-verbal behavior directly created by users. Based on the analysis of the corpus, we propose a Bayesian model to automatically compute the virtual agent's non-verbal behavior conveying interpersonal attitudes.

1 Introduction

Nowadays, virtual agents are more and more used to endowed particular social roles during human-machine interaction, such as actors in video games [1], assistants [2], or tutors [3]. To perform successfully social roles, virtual agents should be able to convey different interpersonal attitudes, such as being friendly, hostile or dominant. Interpersonal attitude is an "affective style that can be naturally or strategically employed in an interaction with a person or a group of persons" [4]. One's interpersonal attitude is expressed through verbal but also non-verbal behavior [5]. For instance, a more dominant person tends to do wider gestures [6].

In this paper, we aim at endowing virtual agents with the capacity to express different interpersonal attitudes through their non-verbal behavior. In particular, we focus on the type of behavior the virtual agent should display to communicate a given attitude. In this paper, we do not focus on the strategy employed by the agent. In order to identify how a virtual agent may convey interpersonal stances through its non-verbal behavior, we have collected a corpus of virtual agent's non-verbal behavior directly created by users. Based on the collected corpus, we have developed a Bayesian network to compute the virtual agent's non-verbal behavior depending on its interpersonal attitude. This paper is organized as follows. In Sect. 2, we present the theoretical background highlighting how interpersonal attitude is expressed through human's non-verbal behavior.

In Sect. 3, existing virtual agents endowed with the capabilities to display social non-verbal behavior are presented. In Sect. 4, we describe the platform we have developed to collect a corpus, directly created by users, of virtual agent's non-verbal behavior conveying different attitudes. In Sect. 6, we explain a Bayesian model to automatically generate virtual agent's non-verbal behavior depending on its interpersonal attitude. We conclude in Sect. 7.

2 Theoretical Background on Interpersonal Attitudes

A common way to represent interpersonal attitudes or relations is to follow the Argyle's representation [7, 8]. This representation is composed of two dimensions: *dominance* (also called status or agency) and *liking* (also called affiliation or communion). This is sometimes referred to as the *Interpersonal Circumplex* (Fig. 1). The axes are labeled with the dominant, submissive, friendly and hostile terms. An interpersonal attitude is then represented by a point in the circumplex, *i.e.* a value on the dominance axis and on the liking axis. Several researchers in Human and Social Sciences have explored how interpersonal attitudes are conveyed through non-verbal behavior. They show that interpersonal attitude is mainly conveyed by several modalities from the upper part of the body like facial expression, gestures or gaze [6, 9]. In [6], they report that people with a more dominant attitude do more and wider gestures. A more submissive attitude leads to less expressive faces [9] and a friendly attitude to more smiles [5]. Head orientation is also different depending on the attitude; a more dominant or friendly person will use more upward orientation [6, 9]. Mutual gaze conveys an attitude of dominance or friendliness as shown in [5]. Moreover some works highlighted the influence of the gender of the interactants on one's non-verbal behavior [10, 11]. Based on these results, we have constructed a platform to collect data on the non-verbal agent's behavior associated to an interpersonal attitude. Before describing this platform, in the next section, we present existing works in virtual agents.

3 Related Works on Virtual Agents

In this section, we present the existing works on virtual agents with social abilities. They are usually referred to as *relational agents*. Laura[12] is one of the first relational agents. She is a fitness coach users had to interact with on a long-term duration. The relations evolve in the same way for every user. The more a user interacts with her, the friendlier is her non-verbal behavior (proximity, mutual gaze, higher hand gestures frequency and head nods). Eva [13] is expressing emotions and is also endowed with a social relations model, following the *Interpersonal Circumplex*. Social relations do not affect directly the behavior of Eva, but the emotions generated within the agent. In the project Demeanour [14], the authors also use the Interpersonal Circumplex to represent social relations between two agents. Gaze, gestures and postures of the agents change depending on their social relations. The behavior model is based on a psychology model

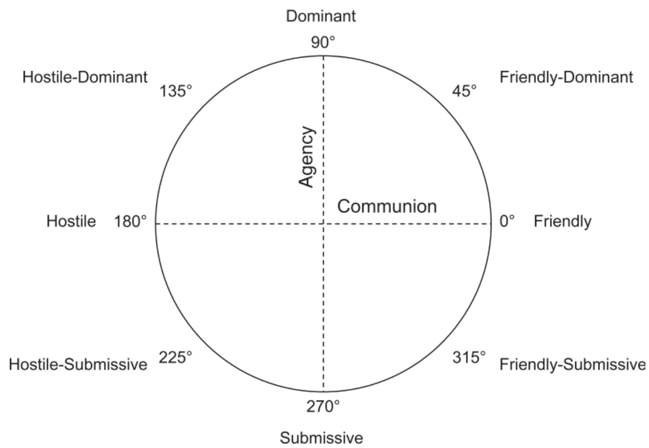

Fig. 1. Example of an Interpersonal Circumplex [8]

and on informal observations of people. In [15], a study is conducted to assess how users perceive attitude (hostile, friendly) and extraversion during the first seconds of an encounter. The differences in behavior (smile, gaze and proximity) are modeled from the literature in Human and Social sciences. In [16], they build a model of non-verbal behavior (gaze, posture and proximity) depending on the conversation role (speaker, addressee, side participant or bystander), the communicative act and the relations between the characters. This model was built by observing actors playing a scenario (the *Gunslinger*) involving the different roles and knowing the interpersonal relations between the characters. While several models of interpersonal attitudes have been proposed, they do not study specifically gender differences in conveying interpersonal attitudes. In our research, we aim to go beyond by considering a larger set of behaviors and gender differences.

We explore four different social attitudes, *Dominant*, *Submissive*, *Friendly* and *Hostile*. We are observing the following non-verbal cues: facial expressions, gazes, head shifts, head movements and arm gestures. Moreover, we also consider two expressivity parameters for the arm gestures, *Spatial* (linked to gesture amplitude) and *Power* (linked to gesture force). We are using a user perceptive approach to collect data about how interpersonal attitudes are encoded through these cues. This data, collected directly from participants in an online application we have developed, is used to generate a computational model of agent's non-verbal behavior depending on its interpersonal attitude.

4 GenAttitude: A Platform to Collect Virtual Agent's Non-Verbal Behavior

As presented in Sect. 2, one's non-verbal behavior may convey particular interpersonal attitude. In order to identify the non-verbal behavior a virtual agent should perform to express social attitudes, we propose a user perceptive approach consisting in asking directly the user to configure the non-verbal behavior of an agent with particular social attitudes. This approach has already been used in [17] to gather data about the features of different types of smiles (amused, polite and embarrassed) and to generate a decision tree for these types of smiles. Whereas in [17], the focus was in the signal of smiles, in the presented work we explore the multimodal behavior of a virtual agent.

Illocutionary Acts. In our work, the attitudes are considered in the context of an interaction. We focus on the role of the locutor[1]. We base our work on the classification of illocutionary acts (or speech acts) proposed by Searle [18]. This classification considers five different categories: assertive, directive, commissive, expressive and declarative. Since research showed that gestures are tightly connected to the content of speech [19, 20] and to cover the five categories of illocutionary acts, we consider a set of six illocutionary acts: *Inform* as an assertive, *Ask* as a directive, *Accept* as a commissive, *Agree* and *Disagree* as expressive and *Deny* as a declarative.

GenAttitude platform. We have developed *GenAttitude* using Flash technology and the virtual agent platform Greta [21]. Flash makes it easy to create an online graphical application and the architecture of Greta allowed us to develop additional modules we needed in order to generate animations. The interface of *GenAttitude*, illustrated in Fig. 2 is inspired by the one proposed in [17]. On the top of the screen, there is a description of the current task. It explains what attitude and what illocutionary act the user has to configure. There are four different possible social attitudes (randomly selected): Dominant, Submissive, Friendly and Hostile. On the right side, there are the different parameters for the non-verbal behavior. The user can change the value of these parameters using radio buttons. The list of parameters as well as their possible values has been designed following the research in Human and Social Sciences presented in Sect. 2. For each parameter, the user can select a value from a discrete set of values. The parameters are the following:

1. The type of facial expression: smile, frown or neutral
2. Gesture: none, head movement only, arm movement or both
3. Amplitude of gesture: small, medium or large
4. Power of gesture: small, medium or strong
5. Head position: straight, up, down or tilt on the side
6. Gaze: gaze at or gaze away

The types of head movements and of arm gestures cannot be modified by the participants. The head movements have been defined to be consistent with the communicative act. When the act is either *Deny* or *Disagree*, the head movement available is a shake. It is a nod otherwise. Concerning the arm gestures, we have

[1] Note that the interpersonal attitude may also be reflected by the non-verbal behavior of a virtual listener

chosen a neutral gesture (not specific to a communicative act). It is a two hands palm open facing up placed in front of the agent. This way, the same gesture is used for each communicative act. When there is no gesture, both hands rest on the agent's belly. Also, it is not possible to select a value for the *Spatial* and *Power* parameters if is not activated (value *gesture only* or *both* for the *Gesture* parameter). In order to avoid the experiment to be biased by a default configuration, the parameters are randomly pre-selected. On the left side, a video plays in loop the animation resulting from the configuration of parameters. The video is changed each time a value for a parameter is changed. Finally, on the bottom of the screen, there is a Likert scale for the user to rate how satisfied he is with the resulting animation.

Procedure Each participant has used *GenAttitude* to indicate the non-verbal behavior of a virtual agent in 6 different situations. Each situation corresponds to a particular social attitude, a particular communicative act and a male or female agent. To avoid an effect of the order of the presentation on the results, the order of the communicative act, the attitude and the gender presented to the participant was counter-balanced.

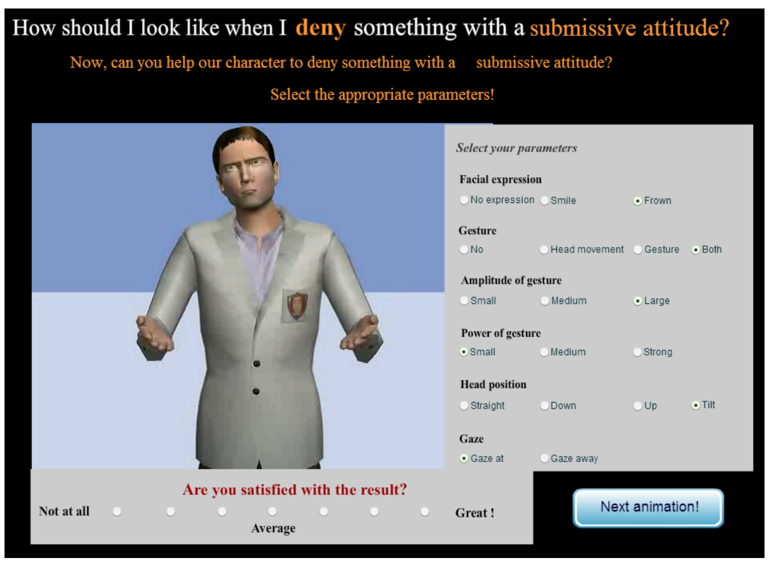

Fig. 2. Screenshot of the Interface of GenAttitude

Generating the videos. Due to the number of parameters and possible values, we have generated 1440 videos. For this purpose, we developed an additional module in the platform Greta. This module takes an FML [22] file as input, generates all combinations of signals (facial expressions, gestures, head movements and

parameters) associated with the intentions specified in the FML file and capture a video of the resulting animation for each combination.
Before making *GenAttitude* available online, 6 pre-tests have been performed in order to ensure the interface was clear and that the tasks were well understood.

5 Statistical Results

5.1 Description

From this experiment, we collected 925 entries from 170 participants (311 entries from female participants) during a week. Each entry corresponds to an illocutionary act, an attitude, a gender and the set of values for each parameter. We had participants from different countries but most of them were from France, aged from 17 to 62 ($M = 28.8$, $SD = 2.8$). In average, the participants were globally satisfied with the created animation: the satisfaction of the participants is in average 5.35 (on a likert scale of 7 points).

5.2 Influence of the Attitude

In order to analyze the collected corpus and to study the correlation between the attitudes, acts, gender and the non-verbal parameters, we have computed Cramer's V χ^2 tests. The χ^2 test compares the distribution frequencies of the outcomes of two variables with a theoretical distribution where the variables are independent. The result of the χ^2 test indicates if two variables are dependent and the Cramer's V test provides the strength of this dependency. The results show significant correlations between the attitude and the *Facial expression* parameter ($\chi^2(6) = 451.65$, $p < 0.005$; Cramer's V= 0.49), the *Gestures* parameter ($\chi^2(9) = 24.0$, $p < 0.005$; Cramer's V= 0.09), the *Power* parameter ($\chi^2(6) = 69.9$, $p < 0.005$; Cramer's V= 0.26), the *Spatial* parameter ($\chi^2(9) = 24.0$, $p < 0.005$; Cramer's V= 0.09), the *Head position* parameter ($\chi^2(9) = 167.3$, $p < 0.005$; Cramer's V= 0.25) and the *Gaze* parameter ($\chi^2(9) = 81.69$, $p < 0.005$; Cramer's V= 0.29). In other words, all the non-verbal parameters are implied in the expression of social attitude.

We also looked at the correlations between the illocutionary act and the parameters. Only the *Facial expression* ($\chi^2(10) = 24.9$, $p < 0.05$; Cramer's V= 0.11) and the *Gestures* ($\chi^2(15) = 89.39$, $p < 0.005$; Cramer's V= 0.18) showed significant correlations. Indeed, positive facial expression was generally selected more for positive illocutionary acts (*Agree*, *Accept*) while the negative one was generally selected more for negative acts (*Disagree*, *Deny*). Regarding the gestures, head movements were more generally selected for negative and positive acts (respectively *Disagree*, *Deny* and *Agree*, *Accept*) and the gesture only (no head movement) were more often chosen for a neutral act (*Ask*, *Inform*). This could be explained by the fact that we introduced a shake for negative acts and a nod for positive and neutral acts.

Moreover, we have looked for correlations between the gender of the agents and the gender of the users on the selected parameters. The results did not reveal

Table 1. Contingency table of the non-verbal parameter and the attitudes

Parameter	Value	Dominant	Friendly	Hostile	Submissive
Facial Expression	negative	**44,64%**	9,40%	**79,20%**	16,81%
	neutral	29,18%	8,55%	12,39%	**46,98%**
	positive	26,18%	**82,05%**	8,41%	36,21%
Gestures	gesture only	27,47%	**30,77%**	24,34%	20,69%
	head only	29,18%	28,21%	26,99%	**34,91%**
	both	**33,05%**	29,49%	**31,86%**	23,28%
	none	10,30%	11,54%	16,81%	21,12%
Power	normal	24,82%	39,01%	23,62%	26,47%
	small	26,95%	**41,84%**	19,69%	**53,92%**
	strong	**48,23%**	19,15%	**56,69%**	19,61%
Spatial	normal	29,08%	**35,46%**	22,05%	17,65%
	small	31,21%	29,08%	29,13%	**56,86%**
	large	**39,72%**	**35,46%**	**48,82%**	25,49%
Head position	down	22,32%	19,23%	**30,53%**	**58,62%**
	straight	30,47%	27,78%	23,45%	13,36%
	tilt	12,45%	**39,32%**	24,78%	18,10%
	up	**34,76%**	13,68%	21,24%	9,91%
Gaze	gaze away	15,88%	17,52%	28,32%	49,14%
	gaze at	**84,12%**	**82,48%**	**71,68%**	**50,86%**

any significant correlations. In other words, the gender of the agent, or of the user, does not seem to have an impact on the selected parameters.

5.3 Discussion

The statistical analysis presented in the previous section shows a significant relationship between attitudes and the selected parameters of the virtual agent's non-verbal behavior. We discuss these results in more details in the following by looking at the most selected values for each attitude.

Dominant. The dominant attitude is mainly characterized by a negative facial expression, the presence of head movements and arm gestures, the absence of gaze avoidance, and an upward position of the head. The gestures are characterized with a *large* spatial parameter and a *strong* power parameter.

Submissive. A submissive attitude is mainly characterized by a neutral facial expression, head movements only (no arm gestures), and an downward position of the head. For the gaze avoidance there is a little preference for the *gaze at* value. Both spatial and power parameters receive a *small* value when the gestures are activated.

Friendly. This attitude is characterized by gestures only, a positive facial expression, a tilt of the head on the side and no gaze avoidance. For the spatial parameter, the *normal* value and the *large* value are the most selected and for the power parameter, the *small* value is the most selected.

Hostile. Similar as the dominant attitude, hostile is characterized using the negative facial expression, both head movements and arm gestures and no gaze avoidance. The same parameters for gesture is selected (*large* and *strong*). However, the head position is *down*.

These results, described Table 1, show close similarities between the way people consider non-verbal behaviors in a human and in an agent. Indeed, people expect from a dominant person more wide gestures or an upward oriented head [6], from a submissive person less expressive faces [6] and from a friendly one more smiles [5]. However, our results contains some differences with the literature. No influence of the gender of the agent or of the user was significant. Also, more gaze avoidance from an hostile or submissive agent was expected but not found.

Based on these results, in the next section, we propose a Bayesian model to automatically generate non-verbal behavior of virtual agent given its social attitude.

6 Bayesian Network Based Model of Virtual Agent's Non-Verbal Behavior

Some computational models of virtual agent's non-verbal behavior are based on a Bayesian network [23, 24]. Bayesian networks are directed acyclic graphs where the nodes represent the variables and the edges between two nodes represent the conditional dependencies between two variables [25]. In [23], the parameters of the non-verbal behavior as well as the context of the interaction are represented by the nodes of the network. As input nodes to describe the context, the previous gesture, the discourse and verbal context and some features of the topic of conversation (for instance position and shape of objects) are used. As output nodes, parameters for the gestures (for instance hand orientation, movement and hand shape) are specified. In our work, we propose to use a similar representation based on a Bayesian network to compute the non-verbal behavior of a virtual agent given its social attitude. We present in details the structure of the network in the next section.

6.1 Structure of the Network

As input nodes for our model, we take the *Interpersonal Attitude* and the *Illocutionary Act*. As output nodes, we consider the non-verbal behavior parameters explored with the *GenAttitude* platform (Section 4). We placed an oriented arc from the input nodes to the output nodes depending on the correlation between input and output nodes. The correlations correspond to those identified in Sect. 5. The result is shown in Fig. 3.

6.2 Parameters of the Bayesian Network

Learning the parameters of a Bayesian network consists in learning the conditional probability distribution for each node. To compute the parameters of the model, we use the data of the collected corpus (Section 5). Indeed, the conditional probabilities can be easily computed from the 925 descriptions of non-verbal behavior associated to the attitudes.

In order to consider the satisfaction indicated by the user on the created non-verbal behavior (Section 4), we have done *oversampling* to give a higher weight to the entries with a high level of satisfaction: each entry has been duplicated n times, where n is the level of satisfaction associated with this entry. So, a non-verbal behavior describing an attitude with a level of satisfaction of 7 is duplicated 7 times whereas a non-verbal behavior with a level of satisfaction of 1 is not duplicated. The resulting data set is composed of 4947 entries.

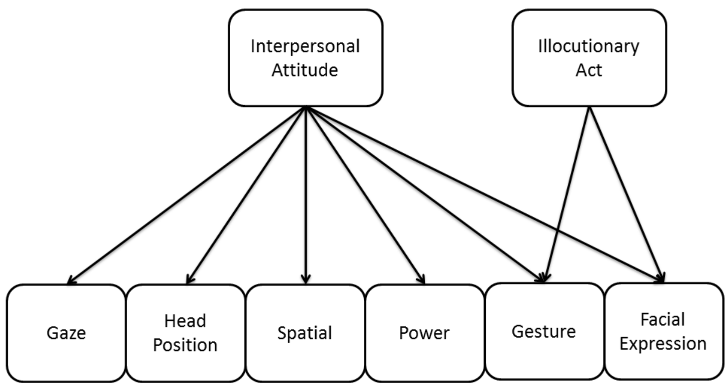

Fig. 3. The Bayesian Network

Outcome of the model. The Bayesian network enables two ways of using our data in the context of interpersonal attitudes of virtual agent. From this network, we can choose an attitude and a communicative act and obtain non-verbal behaviors with different probabilities to be perceived as corresponding to this attitude. This introduces variability in the generation of non-verbal behaviors. Or, from a captured non-verbal behavior (described with our parameters), we can infer which attitude might be conveyed by this behavior. Moreover, this model can be easily extended in the future with new parameters. It could be mixed with the model from [23] for instance. This would allow the model to be able to decide if gestures are activated depending on the communicative act and attitude, and then to decide which shape (hand orientation and hand shape) to use. Including the study in [24], it would extend the model with complex facial expressions.

6.3 Illustrations

In this section, we propose to illustrate the outputs of the proposed model on a concrete example. The agent has to perform an *Inform* illocutionary act with a dominant attitude. Following our Bayesian network, the combination which has the highest probability is a neutral face, gesture only (no head movements), large and strong gesture, an up-oriented head and no gaze avoidance. For the same illocutionary act but with a submissive attitude, the combination with the highest probability is a positive facial expression, no gesture at all and a down-oriented head. The non-verbal behaviors for these attitudes along with other variants are illustrated Fig. 4.

Fig. 4. Screenshot of a virtual agent expressing a social attitude: dominant attitude (top) and submissive attitude (bottom).

7 Conclusion

In this paper, we presented how we developed an online platform in order to collect data from participants about the non-verbal behavior of a virtual agent depending on its interpersonal attitudes. We analyzed these data in order to understand how a virtual agent endowed with interpersonal attitude should behave as a speaker using different illocutionary acts. Then we proposed a Bayesian network built upon these data in order to create a computational model of non-verbal behavior depending on the interpersonal attitude of the agent and on the illocutionary act.

The proposed model could be improved in several ways. For instance, the discrete values on the interface could be replaced by continous values that the user could manipulate through sliders. The description of the task to the user could also be more precise and integrate other elements from the context, such as the agent's emotions. In future works, we aim at analyzing differences in the expression of the attitude depending if the agent is speaking or listening and who his interlocutor is. In the presented study, we have focused on the interpersonal attitude expressed through a communicative intention. However, the attitude also emerges from the interaction depending, for instance, on the reactions of the agent to the user's behaviors. For this purpose, we aim at considering how the global non-verbal behavior of the agent may convey particular attitudes on the overall interaction. Then, in the Interpersonal Circumplex, we only considered the four edges of its two axes as potential attitudes. It would be interesting to expend the possible attitudes, by letting the users rate the value on each axis for instance. Finally, non-verbal parameters may not be independent with each other. We have not analyzed this in this work.

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