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# How a virtual agent should smile?

## Morphological and dynamic characteristics of virtual agent's smiles

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**Abstract.** A smile may communicate different meanings depending on subtle characteristics of the facial expression. In this article, we have studied the morphological and dynamic characteristics of amused, polite, and embarrassed smiles displayed by a virtual agent. A web application has been developed to collect virtual agent's smile descriptions corpus directly constructed by users. Based on the corpora and using a decision tree classification technique, we propose an algorithm to determine the characteristics of each type of the smile that a virtual agent may express. The proposed algorithm enables one to generate a variety of facial expressions corresponding to the polite, embarrassed, and amused smiles.

**Key words:** Smile, Embodied Conversational Agent (ECA), Facial Expression, Decision Tree

## 1 Introduction

Smiling is one of the simplest and most easily recognized facial expressions [1]. Only one muscle, the zygomatic major, has to be activated to create a smile. But a smile may have several meanings – such as amusement, politeness, or embarrassment – depending on subtle characteristics of the smile itself and of other elements of the face that come with the smile. These different types of smile are often distinguished by humans during an interaction. Recently [2, 3] has shown that people also distinguish different types of smile when they are expressed by a virtual agent. Moreover, a smiling virtual agent enhances the human-machine interaction, for instance the perception of the task, of the agent, and the motivation and enthusiasm of the user [4, 5]. However, an inappropriate smile (an inappropriate type of smile or a smile expressed in an inappropriate situation) may have negative effects on the interaction [5].

In this paper, we present a research work that aimed at identifying the morphological and dynamic characteristics of different types of smile. More precisely, we have investigated how a virtual agent may display different types of smile in context-free situations. For this purpose, we have created a web application to collect a virtual agent's smile descriptions corpus directly constructed by users. Based on the corpus, we have used a machine learning algorithm to determine

the characteristics of each type of the smile that a virtual agent may express. As a result, we obtain the algorithm that may be easily implemented in any virtual agent. It enables one to generate a variety of facial expressions corresponding to the polite, embarrassed and amused smiles.

The paper structure is as follow. After giving an overview of existing work on humans' smiles (Section 2.1) and on virtual agents' smiles (Section 2.2), we introduce the web application developed to collect the smiles corpus (Section 3). Section 4 describes the corpus. In Section 5, we present the algorithm to compute the smile's characteristics based on the smiles corpus. We conclude in Section 6.

## 2 Related work

### 2.1 Theoretical background: smiles' types and characteristics

When someone smiles, it does not necessarily mean that he feels happy. Indeed, different types of smile with different meanings can be distinguished. The most common one is the *amused smile*, also called felt, Duchenne, enjoyment, or genuine smile. The amused smile is often opposed to the *polite smile*, also called non-Duchenne, false, social, masking, or controlled smile [6]. Perceptual studies [6] have shown that people unconsciously and consciously distinguish between a smile of amusement and a polite smile. Someone may smile in a negative situation. For instance, a specific smile appears in the facial expression of embarrassment [7], or anxiety [8].

In this paper, as a first step, we focus on the three following smiles: *amused*, *polite* and *embarrassed* smiles. These smiles have been selected because they have been explored in the Human and Social Sciences literature both from the *encoder* point of view (from the point of view of the person who smiles) [7, 1] and from the *decoder* point of view (from the point of view of the one who perceived the smile) [9].

The different smiles have different morphological and dynamic characteristics that enable one to distinguish them. *Morphological characteristics* are, for instance, the mouth opening or cheek raising. *Dynamic characteristics* correspond to the temporal unfolding of the smile such as the velocity. In the literature on smile [9, 7, 1], the following characteristics are generally considered to distinguish the amused, polite and embarrassed smiles<sup>1</sup>:

- *morphological characteristics*: AU6 (cheek raising), AU24 (lip press), AU12 (zygomatic major), symmetry of the lip corners, mouth opening, and amplitude of the smile;
- *dynamic characteristics*: duration of the smile and velocity of the onset and offset of the smile.

<sup>1</sup> Note that other elements of the face, such as the gaze and the eyebrows, influence how a smile is perceived. However, in the presented work, we focus on the influence of the smile and we do not consider the other elements of the face.

Concerning the *cheek raising*, Ekman [10] claims the orbicularis oculi (which refers to the Action Unit (AU) 6 in the Facial Action Coding System [11]) is activated in an amused smile. Without it, the expression of happiness seems to be insincere [12]. However, recently the role of AU6 in the smile of amusement was challenged by Krumhuber and Manstead [13]. *Lip press* (AU24) is often related to the smile of embarrassment [7]. According to Ekman [10], *asymmetry* is an indicator of voluntary and non-spontaneous expression, such as the polite smile. The different types of smile may have different *durations*. The felt expressions, such as the amused smile, last from half a second to four seconds, even if the corresponding emotional state is longer [10, 14]. The duration of a polite or embarrassed smile is shorter than 0.5 second or longer than 4 seconds [1, 10, 14]. Not only the overall duration, but also the course of the expression is different depending on the type of the smiles. The dynamic of facial expressions is commonly defined by three time intervals. The *onset* corresponds to the interval of time in which the expression reaches its maximal intensity starting from the neutral face. Then, the *apex* is the time during which the expression maintains its maximal intensity. Finally, the *offset* is the interval of time in which the expression starting from the maximal intensity, returns to the neutral expression [1]. In the deliberate expressions the onset is often abrupt or excessively short, the apex is held too long, and the offset can be either more irregular or abrupt and short [1].

However, no consensus exists on the morphological and dynamic characteristics of the amused, polite and embarrassed smile. In general, AU6 is more present in amused smile than in polite or embarrassed smile. For instance, according to Ekman the amused smile is characterized by a cheek raising (AU6), the activation of the zygomatic major (AU12) and a symmetry of the zygomatic major. The dynamic characteristics of the amused smile are the smoothness and regularity of the onset, apex, offset and of the overall zygomatic actions, and a duration of the smile between 0.5 and 4 seconds [1]. According to the same author, in the expression of a polite smile, the cheek raising (AU6) is absent, the amplitude of the zygomatic major (AU12) is small, the smile is slightly asymmetric, the apex is too long, the onset too short, the offset too abrupt, and the lips may be pressed [1]. The embarrassed smile is characterized by the lips pressed, the closed mouth, a small amplitude, the absence of AU6, asymmetry, and a duration shorter than 0.5 seconds or longer than 4 seconds [7, 1].

## 2.2 Smiling virtual agents

In order to increase the variability of virtual agent's facial expressions, several researchers have considered different virtual agent's smiles. For instance, in [15], two different types of smile: an amused and polite are used by a virtual agent. The amused smile is used to reflect an emotional state of happiness whereas a polite smile (called fake smile in [15]) is used in a case of a sad virtual agent. The amused smile is represented by lip corners raised, lower eyelids raised, and

an open mouth. The polite smile is represented by an asymmetric raising of the lip corners and an expression of sadness in the upper part of the face.

In [2], virtual agents mask a felt negative emotion of disgust, anger, fear or sadness by a smile. Two types of facial expression were created according to the Ekman’s description [16]. The first expression corresponds to a felt emotion of happiness. The second one corresponds to the other expression (e.g. disgust) masked by unfelt happiness. In particular, the expression of unfelt happiness lacks the AU6 activity and is asymmetric (see Section 2.1). A perceptive test has enabled the authors to measure the impact of such fake expressions on the user’s subjective impression of the agent. The participants were able to perceive the difference, but they were unable to explain their judgment. The agent expressing an amused smile was perceived as being more reliable, trustable, convincing, credible, and more certain about what it said compared to the agent expressing a negative emotion masked by a smile.

In [4], the authors have explored the impact of varying dynamic characteristics of smile in virtual faces on the users’ job interview impressions and decisions. The results show that smiles with long onset and offset durations were associated with “authentic smiles” (amused smile). Fake smiles were characterized by short onset and offset durations. The total duration of the smiles was equal (4 seconds). In the interaction, the type of smiles used by the virtual agents has an impact on the user’s perception: the job is perceived as more positive and suitable in case of authentic smiles. Globally, whatever is the smile (fake or authentic), a smile increases the positive perception of the agent.

Niewiadomski and Pelachaud [3] proposed an algorithm to generate complex facial expressions, such as masked or fake expressions. An expression is a composition of eight facial areas, each of which can display signs of emotion. For complex facial expressions, different emotions can be expressed on different areas of the face. In particular, it is possible to generate different expressions of joy: a felt and a fake one. The *felt* expression of joy uses the reliable features (AU6), while the second one is asymmetric.

Several other virtual agents *smile* during an interaction, for instance to express a positive emotion [17], or to create a global friendly atmosphere [5]. Generally, such virtual agents use only one type of smiles: the *amused smile*. In this work, we aim at exploring the different types of smiles a virtual agent may perform. Whereas previous research (presented above) has analyzed the impact of different smiles on the users’ perception of the agent or of the interaction, in the work presented in this article, we focus on the different smiles that a user may perceive. More particularly, we have conducted a study to analyze the morphological and dynamic characteristics of the amused, polite and embarrassed smiles of a virtual agent. In the next section, we present the platform we have developed to study such smiles.

### 3 E-smiles-creator: Web Application for Smiles Data Collection

In order to identify the morphological and dynamic characteristics of the amused, embarrassed and polite smile of a virtual agent, we have created a web application, called *E-smiles-creator*, that enables a user to easily create different smiles on a virtual agent's face. The interface of the *E-smiles-creator* is composed of 4 parts (Figure 1):

1. on the upper part, a description of the task: the smile that the user has to create, for instance an amused smile;
2. on the left part, a video showing, in loop, the virtual agent animation;
3. on the right part, a panel with different smile parameters (such as the duration) that the user may change to create the smile (the video on the left changes accordingly);
4. and on the bottom part, a Likert scale that enables the user to indicate his satisfaction related to the smile he has created.

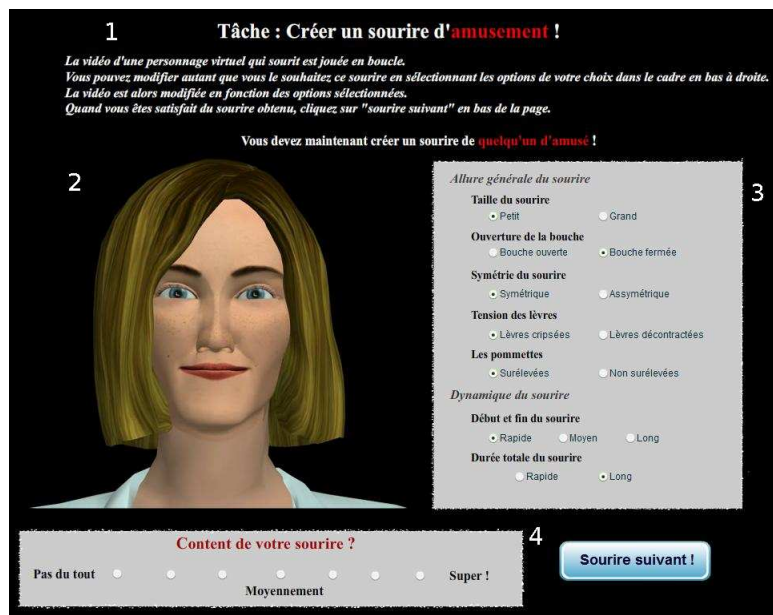


Fig. 1. Screenshot of the *E-smiles-creator*

Using *E-smiles-creator*, the user can generate any smile by choosing the combination of seven parameters. Any time he changes the value of one of the parameters, a corresponding video is automatically played. Based on the research on human smile (see Section 2.1), we consider the following morphological and

dynamic characteristics of a smile: the activation of AU6 (cheek raising), the activation of AU24 (lip press), the activation of AU12 (zygomatic major), the symmetry of the lip corners, the mouth opening, the amplitude of the smile, the duration of the smile and the velocity of the onset and the offset of the smile. Accordingly, on the right part of the *E-smiles-creator* interface (Figure 1, panel 3), the user may select these parameters of the smile. The video of the smiling agent will correspond to a smile with the selected parameters. We have considered two or three discrete values for each of these parameters: small or large smile (for the amplitude); open or close mouth; symmetric or asymmetric smile; tensed or relaxed lips (for the AU24); cheekbone raised or not raised (for the AU6); short (1.6 seconds) or long (3 seconds) total duration of the smile, and short (0.1 seconds), average (0.4 seconds) or long (0.8 seconds) begin and end of the smile (for the onset and offset)<sup>23</sup>. Considering all the possible combinations of these discrete values, we have created 192 different videos of smiling agent. An example of a sequence of images of a video of the virtual agent smiling is illustrated Figure 2. The *E-smiles-creator* has been created using Flash technol-



**Fig. 2.** Example of a sequence of the first images of a video of the smiling virtual agent

ogy to enable a diffusion on the web. The interface of the *E-smiles-creator* is in French. The user can create one animation for each type of smile. Each time, the user also has to express his level of satisfaction concerning the smile he has created. The order of smiles to be illustrated as well as the initial values of the seven parameters are chosen randomly.

#### 4 Description of the Smiles corpus

By asking people through a web browser to participate to a study on smiles using *E-smiles-creator*, we have collected 1044 smile descriptions: 348 descriptions for

<sup>2</sup> The values of the onset and the offset have been defined to be consistent with the values of the duration of the smile

<sup>3</sup> As a first step, discrete variables have been considered. To obtain a more fine-grained description of smiles, continuous variables could be considered.

each smile (amused, polite, and embarrassed). 348 subjects have participated to this study (195 females and 153 males). Each participant has created one smile of amusement, politeness and embarrassment. The average participants' age is 30 years. The subjects are mainly French. In average, the subjects are satisfied by the created smiles (5.28 on a Likert scale of 7 points)<sup>4</sup>. Below, we describe the most frequent amused, polite and embarrassed smiles that appear in the smiles corpus.

Table 1 presents the characteristics of the most frequently selected parameter values of amused smiles. In the table, the second column (for instance *# amused*) represents the number of amused smiles (out of 348 amused smiles) defined with the parameter values of the line of the table. For instance, 49 out of 348 amused smiles have been defined with a large size, an open mouth, a symmetry, no lips tension, an activated AU6, an onset and an offset of 0.1 second and a total duration of 3 seconds (first line of the Table 1). Globally, the amused smiles are mainly characterized by a large amplitude, an open mouth, and relaxed lips. Most of them also contain the activation of the AU6, and a long global duration.

Table 2 illustrates the characteristics of the most frequently selected parameter

id	# amused	size	mouth	symmetry	lips tension	AU6	onset/offset	duration
1	49	large	open	yes	no	yes	0.1s	3s
2	43	large	open	yes	no	yes	0.8s	3s
3	30	large	open	yes	no	yes	0.4s	3s
4	22	large	open	no	no	yes	0.8s	3s
5	21	large	open	no	no	yes	0.1s	3s
6	20	large	open	no	no	yes	0.4s	3s
7	9	large	open	yes	no	yes	0.1s	1.6s
8	8	large	open	yes	no	no	0.8s	3s

**Table 1.** The characteristics of the amused smiles in the most frequently selected videos of amused smiles

values of embarrassed smiles. Compared to the amused smiles, the embarrassed smiles often have small amplitude, a closed mouth, and tensed lips. They are also characterized by the absence of AU6. Table 3 describes the characteristics of the most frequently selected parameter values of polite smiles. The polite smiles are mainly characterized by a small amplitude, a closed mouth, a symmetry, relaxed lips, and an absence of AU6. We also analyzed the frequency of the occurrence of each feature separately for each type of smiles. The contingency table is presented Table 4.

<sup>4</sup> Globally, the user's satisfaction is the same for the three smiles (between 5.2 and 5.5)





**Fig. 3.** Images of amused smiles at their apex with the id 1, 4, and 8 in the Table 1

id	# embarrassed	size	mouth	symmetry	lips tension	AU6	onset/offset	duration
1	19	small	close	no	yes	no	0.1s	1.6s
2	18	small	close	no	yes	no	0.4s	3s
3	16	small	close	yes	yes	no	0.4s	3s
4	13	small	close	no	yes	no	0.8s	1.6s
5	11	small	close	yes	yes	no	0.1s	1.6s
6	11	small	close	no	yes	no	0.8s	3s
7	9	small	close	no	yes	yes	0.4s	3s
8	8	small	close	no	yes	no	0.4s	1.6s

**Table 2.** The characteristics of the embarrassed smiles in the most frequently selected videos of embarrassed smiles

## 5 Smiles Decision Tree Learning

In this section we propose an algorithm to generate different types of smile in virtual agent. It allows an agent to display various polite, amused or embarrassed smiles. Our approach is based on machine learning methodology and on the data presented in the previous section.

### 5.1 The decision tree

In order to analyze the smiles corpus, we have used a *decision tree learning* algorithm to identify the different morphological and dynamic characteristics of the amused, polite and embarrassed smiles of the corpus. The input variables (predictive variables) are the morphological and dynamic characteristics and the target variables are the smile types (amused, embarrassed, or polite). Consequently, the nodes of the decision tree correspond to the smile characteristics and the leaves are the smile types. We have chosen the decision tree learning because this technique has the advantage to be well-adapted to qualitative data and to product results that are interpretable and that be easily implemented in a virtual agent.

To create the decision tree, we took into account the level of satisfaction indicated by the user for each created smile (a level that varied between 1 and



**Fig. 4.** Images of embarrassed smiles at their apex with the id 1, 3, and 7 in the Table 2

id	# polite	size	mouth	symmetry	lips tension	AU6	onset/offset	duration
1	16	small	close	yes	no	no	0.4s	3s
2	12	small	close	yes	no	no	0.8s	3s
3	11	small	close	yes	no	no	0.4s	1.6s
4	11	large	close	yes	no	no	0.4s	3s
5	10	small	close	yes	no	no	0.8s	1.6s
6	10	small	close	yes	yes	no	0.4s	1.6s
7	9	small	close	yes	no	no	0.1s	3s
8	8	small	close	yes	no	no	0.1s	1.6s

**Table 3.** The characteristics of the polite smiles in the most frequently selected videos of polite smiles

7). More precisely, in order to give a higher weight to the smiles with a high level of satisfaction, we have done *oversampling*: each created smile has been duplicated  $n$  times, where  $n$  is the level of satisfaction associated to this smile. So, a smile with a level of satisfaction of 7 is duplicated 7 times whereas a smile with a level of satisfaction of 1 is not duplicated. The resulting data set is composed of 5517 descriptions of smiles: 2057 amused smiles, 1675 polite smiles, and 1785 embarrassed smiles.

To construct the decision tree, we have used the free data mining software TANAGRA [18] that proposes several data mining methods for data analysis. We have used the method CART (Classification And Regression Tree) [19], a popular and powerful method to induce decision tree. The resulting decision tree is represented in Figure 6. We have set a minimum size of node to split of 75 to avoid a large number of leaves and then an uninterpretable tree. The resulting decision tree is composed of 39 nodes and 20 leaves. All the input variables (the smile characteristics) are used to classify the smiles.

To compute the error rate, a 10-folds cross-validation (with 5 trials) has been performed. The global error rate is 27.75%, with a 95% confidence interval of 1.2%: the global error rate is then in the interval [26.55%, 28.95%]. An analysis of the error rate for each smile type shows that the amused smiles are better classified (18 % of error) than the polite (34% of error) and the embarrassed



**Fig. 5.** Images of polite smiles at their apex with the id 1, 4, and 6 in the Table 3

variable	value	amused	embarrassed	polite
size	small	16,4%	73,1%	67,7%
	big	83,6%	26,9%	32,3%
mouth	close	14,4%	81,8%	76%
	open	85,6%	18,2%	24%
symmetry	sym.	59,9%	40,5%	67,1%
	assym.	40,4%	59,1%	32,9%
lips tension	no tension	92,2%	25,4%	69,4%
	tension	7,8%	74,6%	30,6%
AU6	no	21,6%	59%	58,9%
	yes	78,4%	41%	41,1%
onset/offset	short	33,4%	28,9%	30,3%
	average	30,3%	39,6%	37,1%
	long	36,3%	31,5%	32,6%
duration	short	15,6%	43,6%	42,9%
	long	84,4%	56,4%	57,1%

**Table 4.** Contingency table of the smile's characteristics and the smile types

smiles (31% of error). Indeed, the confusion matrix reveals that the polite and embarrassed smiles are often confused each other compared to the amused smiles.

In the next section, we discuss in more details how the resulting decision tree can be used to identify the smiles that a virtual agent could express.

## 5.2 Smile selection based on decision tree

Our smiles decision tree reveals 20 different smile patterns, corresponding to the 20 leaves of the tree. Ten leaves are labeled as polite smiles, 7 as amused smiles, and 3 as embarrassed smiles. Because some branches of the tree do not contain a value for each morphological and dynamic characteristics, more than 20 smiles may be created from our decision tree. For instance, for the first polite smile pattern that appears in the tree (indicated by a black arrow on Figure 6), the size of the smile, its duration, and the velocity of the onset and offset are not

## Decision tree

- MOUTH\_OPEN in [open]
  - SMILE\_SIZE in [small]
    - LIPS\_TENSION in [no\_tension]
      - SMILE\_DURATION in [short] then SMILE\_TYPE = **polite** (60,40 % of 101 examples)
      - SMILE\_DURATION in [long]
        - SMILE\_SYM in [sym]
          - SMILE\_AU6 in [no\_AU6] then SMILE\_TYPE = **polite** (66,00 % of 50 examples)
          - SMILE\_AU6 in [AU6] then SMILE\_TYPE = **amused** (64,58 % of 48 examples)
          - SMILE\_SYM in [asym] then SMILE\_TYPE = **amused** (60,53 % of 76 examples)
    - LIPS\_TENSION in [tension]
      - SMILE\_SYM in [sym] then SMILE\_TYPE = **polite** (61,11 % of 54 examples)
      - SMILE\_SYM in [asym] then SMILE\_TYPE = **embarrassed** (69,09 % of 55 examples)
  - SMILE\_SIZE in [large]
    - LIPS\_TENSION in [no\_tension]
      - SMILE\_DURATION in [short]
        - SMILE\_AU6 in [no\_AU6] then SMILE\_TYPE = **polite** (52,63 % of 57 examples)
        - SMILE\_AU6 in [AU6] then SMILE\_TYPE = **amused** (73,08 % of 130 examples)
      - SMILE\_DURATION in [long] then SMILE\_TYPE = **amused** (89,38 % of 951 examples)
    - LIPS\_TENSION in [tension]
      - SMILE\_ONOFFSET in [short,medium] then SMILE\_TYPE = **amused** (41,67 % of 34 examples)
      - SMILE\_ONOFFSET in [long] then SMILE\_TYPE = **embarrassed** (61,29 % of 31 examples)
- MOUTH\_OPEN in [close]
  - LIPS\_TENSION in [no\_tension]
    - SMILE\_SYM in [sym]
      - SMILE\_AU6 in [no\_AU6] then SMILE\_TYPE = **polite** (84,05 % of 370 examples)
      - SMILE\_AU6 in [AU6]
        - SMILE\_SIZE in [small] then SMILE\_TYPE = **polite** (66,12 % of 121 examples)
        - SMILE\_SIZE in [large]
          - SMILE\_ONOFFSET in [short,medium] then SMILE\_TYPE = **amused** (45,00 % of 36 examples)
          - SMILE\_ONOFFSET in [long] then SMILE\_TYPE = **polite** (67,27 % of 55 examples)
    - SMILE\_SYM in [asym]
      - SMILE\_DURATION in [short] then SMILE\_TYPE = **polite** (61,84 % of 152 examples)
      - SMILE\_DURATION in [long]
        - SMILE\_SIZE in [small] then SMILE\_TYPE = **polite** (53,72 % of 121 examples)
        - SMILE\_SIZE in [large]
          - SMILE\_AU6 in [no\_AU6] then SMILE\_TYPE = **amused** (57,41 % of 54 examples)
          - SMILE\_AU6 in [AU6] then SMILE\_TYPE = **polite** (41,46 % of 41 examples)
  - LIPS\_TENSION in [tension] then SMILE\_TYPE = **embarrassed** (70,60 % of 1085 examples)



Fig. 6. Smiles Decision Tree

specified. Consequently, this polite smile pattern can be expressed by the virtual agent in 12 different manners.

In order to identify the smile that the virtual agent should express, we propose an algorithm based on the resulting decision tree. We suppose that as input of the algorithm we have the type of smile the virtual agent should express (amused, polite, or embarrassed) and a value, between 0 and 1, called *importance of smile recognition*. This value expresses both the importance that the smile is well-recognized by the user, and the variability of smiles that the virtual agent could express. The closer the value is to 1 (resp. 0), the more it is important (resp. it is not important) that the smile is recognized by the user as embarrassed, amused, or polite. But, at the same time, the variability is lower. Indeed, a high value implies few possible smiles to express whereas an average value enables the virtual agent to express several different smiles. For instance, an input of the algorithm (*polite*; 0, 9) means that the virtual agent has to express a polite smile and it is important that this smile is perceived as polite by the user. However, an input (*polite*; 0, 6) gives more polite smile variability.

The algorithm to determine the virtual agent’s smile is composed of two steps: a first step aims at selecting the smile pattern in the tree, and the second step determines the smile from the pattern.

In the first step of the algorithm, the *importance of smile recognition* is used to select the appropriate smile in the decision tree. More precisely, for each leaf of the tree, we compute the 95% confidence interval from the classification rate and the number of examples in the leaf (Figure 6) using the formula:  $r = 1.96\sqrt{\frac{p(1-p)}{N}}$  such as  $N$  is the number of examples and  $p$  the classification rate. The 95% confidence interval is then  $[p - r, p + r]$ . For instance, for the first polite smile appearing in the tree (indicated by a black arrow on Figure 6), 60.41% of 101 examples of smile with these characteristics are well-classified (Figure 6). The 95% confidence interval for this leaf is  $[60.41 - 9.5, 60.41 + 9.5]$ . The confidence interval enables us to consider the number of examples in the classification rate. Finally, the selected smile will be the one with the specified type and with the smallest confidence interval containing, or the closest to, the importance of smile recognition value. For instance, the selected smile for a polite smile with an importance of 0.9 will be the fifth polite smile that appears in the tree (with the classification rate 84.05% on 370 examples, so, the 95% confidence interval  $[80.32; 87.79]$ ): a symmetric smile with a closed mouth, relaxed lips, and no AU6.

In the second step of the algorithm, in order to determine the smile’s characteristics not defined in the tree, we consider the contingency table representing the frequency of smile types for each characteristic (Table 4). For instance, if the selected smile is the first polite smile that appears in the tree (indicated by a black arrow on Figure 6), the following characteristics are not specified in the tree: the size of the smile, its duration, and the velocity of the onset and offset. Because in the contingency table, it appears that a majority of polite smiles have a small size, long duration, and an average velocity of the onset and offset, we consider a smile with such characteristics and the characteristics described in the branch of the tree leading to the selected smile.

Finally, the proposed algorithm enables one to determine the morphological and dynamic characteristics of the smile that a virtual agent should express given the type of smile and the importance that the user recognizes the expressed smile. The advantage of such a method is to consider, not only one amused, embarrassed, or polite smile but several smile types. That enables one to increase the variability of the virtual agent's expressions. Compared to the literature on human smiles [1, 7, 9], the decision tree contains the typical amused, polite and embarrassed smiles as reported in the literature (see Section 2.1). However, it contains also amused, polite, and embarrassed smiles with other morphological and dynamic characteristics.

## 6 Conclusion

In conclusion, in this paper, we have proposed an algorithm to determine the morphological and dynamic characteristics of virtual agent's smiles of amusement, politeness, and embarrassment. The algorithm has been defined based on a virtual agent's smiles corpus constructed by users and analyzed with a decision tree classification technique. Such an algorithm enables us to consider not only one specific smile for each type, but several smiles with different characteristics. The proposed algorithm allows for the generation of different smiles and for choosing between an higher potential smile recognition and variability. Depending on this value, the number of smiles that a virtual agent may express for a given smile type (amused, polite, or embarrassed) varies from one (high value of importance) to several (average value of importance).

Because we cannot guarantee that the decision-tree learning algorithm returns the optimal decision tree, the next step of this work is an evaluation of the proposed method to verify that the smiles selected by our algorithm are perceived by the user as relevant in amusement, polite and embarrassed contexts. Other machine learning techniques may also be explored, for instance SVM (Support Vector Machine). This technique has some advantages compared to decision tree, for instance stability, but it remains a black box. Lastly, the work presented in this paper has been conducted in the specific context of a western culture (mainly French culture), with a specific female virtual agent, and in context-free situations. We aim at extending this work by considering the influence of the social context on the type of smile expressed by the virtual agent. Moreover, using the same method, we aim at studying other types of smile identified in the literature, such as for instance melancholy or stifled smile [20].

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