Linguistic Issues in Facial Animation

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Abstract

Our goal is to build a system of 3D animation of facial expressions of emotion correlated with the intonation of the voice. Up till now, the existing systems did not take into account the link between these two features. We will look at the rules that control these relations (*intonation/emotions* and *facial expressions/emotions*) as well as the coordination of these various modes of expressions. Given an utterance, we consider how the messages (what is *new/old* information in the given context) transmitted through the choice of accents and their placement, are conveyed through the face. The facial model integrates the action of each muscle or group of muscles as well as the propagation of the muscles' movement. Our first step will be to enumerate and to differentiate facial movements linked to emotions as opposed to those linked to conversation. Then, we will examine what the rules are that drive them and how their different functions interact.

Key words: facial animation, emotion, intonation, coarticulation, conversational signals

1 Introduction

The face is an important and complex communication channel. While talking, a person is rarely still. The face changes expressions constantly. Emotions are part of our daily life. They are one of the most important human motivations. They are mainly expressed with the face and the voice. Faces have their own language where each expression is not only related to emotions, but is also linked to the intonation and the content of speech, following the flow of speech. Many linguists and psychologists have noted the importance of spoken intonation for conveying different emotions associated with speakers' messages. Moreover, some psychologists have found some universal facial expressions linked to emotions and attitudes. Thus, in order to improve facial animation systems, understanding such a language and its interaction with intonation is one of the most important steps.

There already exist some facial animation systems which incorporate speech and facial expression. F. Parke **[PAR82], [PAR90], [LEW87]** was the first one to propose a facial model whose animation was based on parameters which effect not only the structure of the model but also its expressions (opening the mouth, raising the eyebrows). N. Magnenat-Thalmann and D. Thalmann, for their movie "Rendez-vous à Montreal" **[MAG87]** differentiated two levels of facial expressions (one for the shape of the mouth for phonemes and the second for emotions), and they control their model through parameters. The separation between conformation parameters and expression parameters imply the independence of the production of an expression and the considered face. But, the use of a limited set of parameters enhances a limited set of facial expressions. Various animations such as "Tony de Peltrie" **[BER85]** and "Sextone for President" **[KLE88]** were made from a library of digitized expressions. Such systems are very tedious to manipulate and are valid for one particular facial model only.

M. Nahas, H. Huitric and M. Saintourens defined a B-spline model **[NAH88]** where the animation is done using given control points. K. Waters **[WAT87], [WAT90]** simulated muscle motion with a 2-D

deformation function. Lip shapes for each visible vowel and consonant were defined in the same way. He recorded real actors and manually matched lip positions and phonemes. But, collecting this type of data for these last two models is very difficult. On the other hand, point-to-point control has the advantage of more realistically producing the facial tissue.

D. Hill, A. Pearce, and B. Wyvill, using F. Parke's parametric model **[PEA86], [HIL88], [WYV90]** presented an automatic process for synchronizing speech and lip movements. They approach expressions through a set of rules where every element (of the sound and of the face) can be modified interactively through the use of parameters, however this model would be enhanced if the control was based on the properties of facial muscles **[HIL88]**.

No system up to now has considered the link between intonation and emotion to drive their system.

The facial model integrates the action of each muscle or group of muscles as well as the propagation of the muscles' movement. It is also adapted to the **FACS** notation (Facial Action Coding System) created by P. Ekman and W. Friesen **[EKM78]** to describe facial expressions.

Our work will resolve the difficulty of manipulating the action of each muscle by offering to the user a higher level of animation by lip synchronization and automatic computation of the facial expressions related to the patterns of the voice. We will differentiate facial expressions linked to emotion from nonexpressive ones. We will elaborate a repertory of such movements.

The computation of the facial expressions linked to one particular utterance with its intonation and emotion is done independently of the facial model. Contrary to the technique of using a stored library of expressions **[BER85], [KLE88]** which computes facial expressions for one model only, this method used the decomposition of the facial model into two levels: the physical level (described in previous sections) and the expression level. The facial expressions may be applied to any other facial model (having the same underlying structure).

After defining what *emotion* is for present purposes, we introduce our facial model. We also present the intonational system we are using and the characteristics of the voice for each of the emotions we are looking at.

Finally, we will characterize one by one the various types of facial expressions. Specifically, we will look at how we solve lip synchronization and coarticulation problems.

2 Emotion

An emotion is generated not only by the perception of an action but also by its signifigance to us. It is a function of our memories, our present and future motivations. Emotion is described as a process **[SCH88]**, **[EKM89]**, with various components such as physiological responses (visceral and muscular states), autonomic nervous system and brain responses, verbal responses (vocalizations), memories, feelings and facial expressions. For example, anger can be characterized by muscle tension, decrease of salivation, lowered brow, tense lips, increase of the heart rate. Each emotion modifies in a particular way the physiology of a being. The variations of physical organs affect the vocal track while the variations of muscle actions affect the facial expressions.

Six emotions (anger, disgust, fear, happiness, sadness and surprise) were found to have universal facial expressions **[EKM75]**. We have chosen to study these. There are three main areas in the face where changes occur: the upper part of the face with the brows and forehead, the eyes, and the lower part of the face with the mouth **[EKM75]**. Each emotion is characterized by specific facial changes: fear is recognized by the raised and drawn together eyebrows and lips stretched tense; sadness is characterized by the inner side of the brows drawn up, the upper eyelid inner corner raised and the corners of the lips down (Figure 1).

3 Other Facial Expressions and their Rules

Animating the face by specifying every action manually is a very tedious task and often does not yield every subtle facial expression. While talking, a person not only uses his lips to talk, but his eyebrows may raise, his eyes may move, his head may turn, he may blink...

3.1 Clustering of the Facial Expressions

All facial expressions do not necessarily correspond to emotion. Some facial movements are used to delineate items in a sequence as punctuation marks do in a written text. The raising eyebrows can punctuate a discourse and not be a signal of surprise. P. Ekman **[EKM89]** characterizes facial expressions into the following groups:

emblems correspond to movements whose meaning is very well-known and culturally dependent. They are produced to replace common verbal expressions. For example, instead of saying 'sure' or 'I agree' one can nod.

emotional emblems (also called referential expressions or mock expressions) are made to convey signals about emotions. A person uses them to mention an emotion: he does not feel the emotion at the time of the facial action. He only refers to them. It is quite common, when talking about a disgusting thing, to wrinkle one's nose. Such movements are part of the emotional state (wrinkling the nose is part of the facial expression of disgust).

conversational signals (also called illustrators) are made to punctuate a speech, to emphasize it. Raising the eyebrows often accompanies an accented vowel.

punctuators are movements occurring at pauses.

regulators are movements that help the interaction between speaker/listener. They control the speaking turn in a conversation.

manipulators correspond to the biological needs of the face, like blinking the eyes to keep them wet, and wetting the lips.

affect displays are the facial expressions of emotion.

We have to include all these movements to obtain a more complete facial animation. A face can make many more movements such as grimacing, contorting, lip-biting, twitching, and so on, but we are not considering them. They are not related, a priori, to emotion or speech. Also, the consideration of emblems and emotional emblems is out of scope of this study since they imply the voluntary participation of the speaker. They are given by the semantic of the utterance and not (at least directly) by the intonation of the voice.

3.2 Organization of the Rules

The computation of facial expressions corresponding to each item listed above, is done by a set of rules. Two parameters are used to define an action: its type and its time of occurrence. Our rationale is to allow the user to modify one of the parameters for one action without touching any other variable in the system. It is a very useful scheme since the type of actions performed by a person while talking is still not very well-known by researchers. Most of the people show eyebrow movements to accentuate a word but other facial action may be chosen such as nose wrinkling or eye flashes **[EKM79]**. The user just needs to modify the rule which describes the action and need not alter the rules of occurrence. Another unknown parameter is the effective occurrence of an action. Indeed, a paralanguage feature is not always accompanied by a facial movement. The function of the last one is established (focus one word, etc) but their effective existence is uncertain. Thus we need to have access to the timing of the occurrence of an action. Moreover, the attitude of the speaker (what he wants to convey) and his personality are important factors in his facial behavior. But such points are not yet incorporated in the present study. Offering a tool to compute separately each of the above groups of facial expressions offers a better grasp and control over the final animation.

3.3 Synchronism

An important property linking intonation and facial expression (in fact, it is extended to body movement) is the existence of synchrony between them **[CON71]**. Synchrony implies that changes occurring in speech and in body movements should appear at the same time.

Synchrony occurs at all levels of speech. That is, it occurs at the level of phoneme, syllable (these two are defined by how their patterns are articulated), word, phrase or long utterance. Some body and facial motions are isomorphic to these groups. Some of them are more adapted to the phoneme level (like an eye blink), some others at the word level (like a frown) or even at the phrase level (like an hand gesture).

The main point is that there is no part of speech or body motion that is not grouped together in some sort of cluster. This is the basic rule we are using to compute animation in relation to speech.

4 Facial Model

We present here the descriptive notational system and the facial model we are using.

4.1 Facial Action Coding System

Facial Action Coding System or **FACS** is a notational system developed by P. Ekman and W. Friesen [**EKM78**]. It describes all visible facial movements that are either emotional signals or conversational signals. **FACS** is derived from an analysis of the anatomical basis of facial movements. Because every facial movement is the result of muscular action, a system could be obtained based on how each muscle of the face acts to change visible appearance.

One of the constraints of **FACS** is, by its descriptive functionality, that it deals only with movements and what is visible on the face (no other perturbations, like blushing or tears, are considered). They also introduce what they call an Action Unit (**AU**). It is an action produced by one or more muscles.

4.2 Structural Model

Our model of the face was developed by Steve Platt (Figure 1); it is a hierarchically structured, regionally defined object [**PLA85**]. The face is decomposed into regions and subregions. A particular region corresponds to one muscle or group of muscles. Each of them is simulated by specifying the precise location of their attachment to the surface structure. These regions can, under the action of a muscle, either contract or be affected by a propagated movement of an adjacent region. A region can contain 3 types of information:

- physical information (what is displayed on the screen): a set of 3D points.
- functional information (where it is now): how an **AU** will modify the region.
- connective information: to which regions its movements should be propagated in order to bring secondary movement.

We use **FACS** here to encode any basic action. Concurrent actions can occur. In such a case the final position of a region is the summation of movements (or propagation) of all applied **AUs**. The hierarchy of description of the model allows us to modify its physical shape (i.e. the geometrical position of the points) without affecting the functional information (how an action is performed) and vice versa, where no change on the underlying structural definition (connection of the regions) is made. Both types of information are, thus, independent of each other. This model uses **FACS** and simulates the muscle propagation, taking into account secondary motions. It integrates the elasticity of the muscle and the skin. We choose this model for its muscle structures, movement simulation, its hierarchical definition of the face and its decompostion between physical and functional parameters.

5 Intonation

Intonation is defined as the melodic feature of an utterance and can be decomposed into three components linked to: the syntax of an utterance (such as interrogative, declarative), the attitudes of the speaker (what the speaker wants to explicitly show to the listener: for example, politeness, irony) and finally the emotions (involuntary aspects of the speaker's speech) [**SCH84**]. In our current research, we are not considering the

second feature. The third feature, also called *paralanguage* [**CRY75**], is differentiated mainly by the pitch (while frequency is a physical property of sound, pitch is a subjective one), loudness (the perceived intensity of a sound), pitch contour (the global envelope of the pitch), tempo (rate of speech) and pause. For example, anger is characterized by a high pitch level, wide pitch range and large pitch variations. Its intensity has a very high mean, a high range and also high fluctuations. Its articulation is precise and its speech rate fast. Sadness, however, is characterized by a low pitch level, a narrow pitch range and very small pitch variations. Its intensity is soft, its mean low, its range narrow and its fluctuations small. Its speech rate is slow with the highest number of pauses of the longest duration [**CAH89**], [**LAD85**], [**WIL81**].

To define the syntactic structure of intonation, we are using Janet Pierrehumbert's notation [**HIR86**]. Under this definition, intonation consists of a linear sequence of accents. Utterances are decomposed into *intonational* and *intermediate* phrases. Both of them consist of *pitch accent(s)*, a *phrase accent*; intonational phrases are terminated by a *boundary tone*. Different intonational "tunes" composed of these elements are used to convey various discourse-related distinctions of "focus". That is givenness or newness of information, contrast and propositional attitude. Thus they serve to indicate the status of the current phrase related to the next one, for example, the continuation of the same topic or the introduction of a new one.

We can represent the decomposition of an utterance into intonational (or intermediate) phrases by brackets (see below). The appropriate use of intonational bracketing is determined by the context in which the utterance is produced and by the meaning of the utterance (i.e. what the speaker wants to focus on, what he considers as new information versus old). This bracketing is (partially) reflected in intonation.

Consider the sentence *"Julia prefers popcorn"* (the example is related to one discussed in [**STE90**]). The possible intonational bracketings reflect the distinction between an utterance which is about *Who prefers popcorn* or about *What Julia prefers*:

- (Julia)(prefers popcorn)
- (Julia prefers)(popcorn)

These bracketings can be imposed by intonational tones.

For example, in the following context, we will have the following tune:

```
Question: Well, what about JUlia? What does SHE prefer?
Answer: (JUlia prefers) (pOpcorn).
Accent: (L+H*      LH%) ( H*  LL%)
```

(**H** and **L** denote high and low tones which combine in the various pitch accents and boundary tones. **L+H*** and **H*** are different kinds of pitch accent, and **LH%**, **LL%** and **L** below are boundaries.)

By contrast, in the following context, we will have a different bracketing, imposed by a different set of intonational tunes:

```
Question: Well, what about the pOpcorn? Who prefers IT?
Answer: (JUlia) (prefers pOpcorn).
Accent: (H*  L) (        L+H* LH%)
```

These two examples show different intonational patterns. They emphasize different information (in the first context, the new message is *'popcorn'* versus *'Julia'* in the second one). The bracketing of the sentence, the placement of pauses and the type of accents vary also. Consequently the facial conversational signals and punctuators related to the first utterance will differ from those of the second one.

We assume that the input is an utterance already decomposed and written in its phonetic representation with its accents marked in its bracketed elements. For the moment, we are using recorded natural speech to guide our animation. After recording a sentence, we extract from its spectrogram the timing of each phoneme and pause. We would like later on to use analysis-and-resynthesis methods to automate the determination of paralanguage parameters and phoneme timing **[CHA89], [HAM89]** driven by a representation like the above.

6 Steps for Computing Facial Expressions

Each facial expression is expressed as a set of **AUs**. The sentence is scanned at various levels. The lip shapes and blinks are computed at the phoneme level while the conversational and punctuator signals are obtained by its intonational pattern at the word level. First, we compute the list of **AUs** for the given emotion. We add to this list the **AUs** needed for the mouth shape synchronized with each phoneme. Finally, using a set of rules, we compute the conversational signals, the punctuators, head and eye movements, and eyeblinks.

Emotion does not modify the shape of the contour of an utterance, i.e. it does not affect either the type or the placement of the accents (which are defined, indeed, by the context of the utterance, what is new/old information to the speaker). This property allows us to compute every facial action corresponding to the given intonational pattern. Nevertheless, their final occurrence and their type is emotion dependent. The emotion will affect in an overall manner the first computation. In further sections, we will explain how we derive this set of rules.

Our first step for the animation is lip synchronization. Speechreading techniques offer the possibility to define a lip shape for each cluster of phonemes.

6.1 Speechreading

J. Jeffers and M. Barley **[JEF71]** define speechreading as "the gross process of looking at, perceiving, and interpreting spoken symbols". This method is designed for hearing-impaired. These people learn to read speech from lip movements and facial expressions. Unfortunately, there exists a lot of homophonous words; that is, words that look alike on the face, even if they differ in spelling and meaning. These words cannot be differentiated by their lip, jaw or tongue movements. For example, 'b', 'p', and 'm' involve the same facial movements. Moreover, most of the speech sounds are highly, if not completely invisible (they might involve only an obscure tongue movement, for example).

In our case, we are only interested in visible movements. Vowels and consonants are divided into clusters corresponding to their lip shapes. Each of these groups are ranked from the highest to the lowest visible movements (for example, the phonemes 'f', 'v' are part of the top group, the least deformable one, while 's', 'n' are very context dependent). We should notice that such clustering depends on the speech rate and

visual conditions. These are defined by the visual accuracy the listener has of the speaker (such as light on the speaker, and physical distance between speaker and hearer). A person who articulates each word carefully shows more speech movements, of course. The faster a person speaks, the less effort he makes and fewer movements will be produced. With a fast speech rate or under poor visual conditions, the number of clusters diminishes. In addition, the lip shapes of most groups lose their well pronounced characteristics (lips drawn backward for the 'i', lips puckered for the 'o') and tend to have a more neutral position (moderate opening of the mouth).

Intonation of an utterance is the enunciation of a sequence of accented and non-accented phonemes. An accented vowel is differentiated acoustically from the remaining part of the utterance by its longer duration and increased loudness; visually, the jaw dropping motion is a characteristic of accented or emphasized segments.

This phonemic notation, however, does not tell us how to deal with the difficult problem of coarticulation. In the next section, we introduce a first attempt to solve this problem.

6.2 Coarticulation

Coarticulation means "articulatory movements associated with one phonetic segment overlap with the movements for surrounding segments" [**KENT77**]. If one does not consider the problem of coarticulation, incorrect mouth positions can occur.

Speech has been decomposed into a sequence of discrete units such as syllables and phonemes. However, speech production does not follow such constructions. There is an overlap between units during their production, thus the boundaries among them are blurred.

A simple solution to the problem of coarticulation will be to look at the previous, the present, and the next phonemes to determine the mouth positions [**WAT87**]. But in some cases this is not enough, since the correct position can depend on a phoneme up to five positions before or after the current one [**KENT77**].

Forward coarticulation is defined when "an articulatory adjustment for one phonetic segment is anticipated during an earlier segment in the phonetic string" [**KENT77**] while backward coarticulation is defined when "an articulatory adjustment for one segment appears to have been carried over to a later segment in the phonetic string" [**KENT77**]. For example, forward coarticulation arises in a sequence of consonants (not belonging to the highly visible clusters such as 'f', 'v', ...) followed by a vowel, since the lips show the influence of the vowel on the first consonant of the sequence. In the sequence of phonemes *'istrstry'* (example cited in [**KENT77**]) the influence of the 'y' is shown on the first 's' (forward rule). We have implemented these two coarticulation rules.

A complete set of such rules does not exist. To solve particular problems which cannot be solved by these two rules, we consider a three-step algorithm. On the first step, coarticulation rules are applied to all clusters which have been defined as context-dependent. The next pass is to consider relaxation and contraction time of a muscle and finally to look at the way two consecutive actions are performed. Therefore, the speech context is considered.

After the first computation, we check that each action (**AU**) has time to contract after the previous

phoneme (or, respectively, to relax before the next one). If the time between two consecutive phonemes is smaller than the contraction time of a muscle, the previous phoneme is influenced by the contraction of the current phoneme. Similarly, if the time between two consecutive phonemes is smaller than the relaxation time, the current phoneme will influence the next phoneme when relaxing.

Finally, we take into account the geometric relationship between successive actions. Indeed, the closure of the lips is more easily performed from a slightly parted position than from a puckered position. The intensity of an action is rescaled depending on its surrounding context.

At the end of these steps, we obtain a list of **AUs** for each phoneme.

These constraints between adjacent **AUs** are defined by a constant and are easily changed as is relaxation/contraction simulation. Moreover, lip shapes associated with each phoneme are determined by rules and are also easily modified. This provides a tool for phoneticians to study coarticulation problems.

7 Conversational Signals

A stressed segment is often accompanied not by a particular movement but by an accumulation of rapid movements (such as more pronounced mouth motion, blinks, or rapid head movements).

Conversational signals may occur on an accented item within a word, or, it may stretch out over a syntactic portion of the sentence (corresponding to an emphatic movement).

Most of the time these signals involve actions of the eyebrows. P. Ekman [**EKM89**] found that **AU1+2** (the eyebrows raised of surprise) and **AU4** (the frown of anger) are commonly used. Raised eyebrows can occur to signal a question, especially when it is not syntactically defined. Head and eye motions can illustrate a word; an accented word is often accompanied by a rapid head movement ([**HAD84**], [**BUL85**]. A blink can also occur on a stressed vowel [**CON71**].

Each emotion does not activate the same number of facial movements. An angry or happy person will have more facial motions than a sad person. Also, emotion intensity affects the amount and type of facial movements [**COL85**]. Thus we will select the occurrence of conversational signals depending on the emotion and intensity.

8 Punctuators

Punctuators can appear at a pause (due to hesitation) or to signal punctuation marks (such as a comma or exclamation marks) [**DIT74**]. The number of pauses affect the speech rate: a sad person has a slow speech rate due in part to a large number of long pauses, while a frightened person's speech shows very few pauses of short duration [**CAH89**]. Thus the occurrence of punctuators and their type (i.e. their corresponding facial expressions) are emotion-dependent: a happy person has the tendency to punctuate his speech by smiling. Certain types of head movements occur during pauses. A boundary point (between intermediate phrases, for example) will be underlined by slow movement and a final pause will coincide with stillness [**HAD84**]. Eyeblinks can occur also during pauses [**CON71**].

9 Regulators

Regulators correspond to how people take turns speaking in a conversation, or any ritual meeting. We are still in the process of implementing this section. Much study has been given to speaking-turn system. S. Duncan [**DUN74**] enumerates them:

- Speaker-Turn-Signal: is emitted when the speaker wants to give his turn of speaking to the auditor. It is composed of several clues in his intonation, paralanguage, body movements and syntax.
- Speaker-State-Signal: is displayed at the beginning of a speaking turn. It is composed, at the least, of the speaker turning his head away from the listener and the starting of a speaker gesticulation (arms and so on).
- Speaker-Within-Turn: is used when the speaker wants to keep his speaking turn, and assures himself that the listener is following. It occurs at the completion of a grammatical clause; the speaker turns his head toward the listener.
- Speaker-Continuation-Signal: frequently follows a Speaker-Within-Turn. In such case, the speaker turns his head (and eyes) away from the listener.

10 Manipulators

Blinking is the only phenomena we are taking into account in this category. The eye blinks occur quite frequently. They serve not only to accentuate speech but also to address a physical need (to keep the eyes wet). There is at least one eye blink per utterance.

The internal structure of an eye blink, i.e., when it is closed and when it opens, is synchronized with the articulation [**CON71**]. The eye in blinking might close over one syllable and start opening again over another word/syllable. Blink occurrence is also emotion dependent. During fear, tension, and anger, excitement and lying, the amount of blinking increases; it decreases during concentrated thought [**COL85**].

We first compute all the blinks occurring as conversational signals or punctuators. Then, since eyeblinks should occur periodically we add any necessary ones. The period of occurrence is emotion-dependent. This time will be shorter for fear and longer for sadness.

11 Pupil dilation and constriction

The pupil constricts in bright light, while it dilates in weak light. Moreover, a person with light eye color will have the tendency to have larger pupils and will show larger pupil dilation. Pupil changes also occur during emotional experiences. Pupil dilation is followed by pupil constriction during happiness and anger and remains dilated during fear and sadness [**HES75**].

12 Animation

We should note that every facial action (except those involved in the lip synchronization since they are already taking into account by the three-step algorithm) will have three parameters: onset, apex, and offset. Apex corresponds to the time the action is occurring. Onset and offset define the manner of appearance and disappearance of the action;they are emotion dependent. For example, surprise has the shortest onset time while sadness has the longest offset **[EKM84]**.

Having computed the list of **AUs** for each phoneme, the animation can then be performed. We apply the heuristic that quick abrupt changes for a particular portion of the face cannot occur in too short a time. The regions of the face are organized into three sets: one with high movement (like the lips, the brows), one with medium movement (forehead, cheeks), and one with low movement (outer part of the face). We compute the rate of displacement between each consecutive key-frame. That is, the average displacement of all the points inside each region of the face divided by the time separating the two frames. Each point of every frame is then modified by this *"weight"*. The in-between frames are obtained by computing the B-spline going through the weighted points **[FAR90]**. This is the way to handle any brusque movement and some coarticulation problems which the proposed algorithm does not take care of.

13 Example

Let us consider the example introduced in a previous section: *'Julia prefers popcorn'* with the emotion *disgust*. We record this utterance; we find its intonational pattern; we decompose it into a sequence of phonemes (we use Dectalk's notation); and we extract from its spectrogram the timing of each phoneme.

We consider first the computation of the lip shapes. For every phoneme, we find the group (as defined in **[JEF71]** in which it belongs. Figure 3 depicts the lip shapes for the word *'popcorn'* in the case of fast and slow speech rate. The value of the speech rate modifies the clustering of phonemes; lips tend to correspond to a moderate opening of the mouth for fast speech rate. To highly malleable phonemes (such as 'n', 't'), we apply the forward and backward coarticulation rules. In Figure 2, the phoneme /LL/ in the word *'Julia'* receives the same list of **AUs** with lower intensity as its preceding vowel (/UW/ belongs to a less malleable cluster than /YY/; therefore the backward rule is applied for /LL/). Our next step is to consider the environment of each phoneme and its relaxation and contraction times. For the phoneme /YY/ in *'Julia'*, we can notice the apparition of some pucker effect from the phonemes /UW/ and /LL/. The lip shapes for /LL/ do not have enough time to relax completely from their puckered position to their extended lip shapes: Some puckered effect remains, so we have applied a control over time. On the other hand, the pucker position of the item /AO/ from the syllable *'pop'* is altered due to its surrounding lip closures for the two /PP/s, so we applied a control over space.

The emotion gives the overall orientation of the head. For the emotion *disgust*, the head has globally a backward and upward direction. The utterance is a statement: a Speaker-State-Signal (speaker looks away from listener) is emitted and the head is positioned to look down as the speaker reaches the end of the sentence.

Conversational signals appear in this example, on pitch accents under various forms. Eyebrow movements start, for both actions, at the beginning of the considered syllable. Rapid movements around the actual position of the head or a sharp repositionment of small amplitude caracterizes the head motion on the pitch accent. Moreover, blinks acting as conversational signals start at the beginning of the accented syllables and are synchronized at the phoneme level.

Disgust is characterized by few pauses, therefore no pause is found between the two intonational phrases and only the juncture pause at the end of the utterance is considered. Nose wrinkling and a blink occur then. They begin and finish at the same time as the juncture pause. The sentence finishes with slow movement followed by stillness of the head motion.

The last step is to look if more blinks are needed (called periodic blink). In our case, none is needed since already computed blinks occur at a sufficient rate. The Figure 4 summarizes in a table this sequence of corrdinated expressions.

14 Summary

We have presented here a tool which enhances facial animation. Our method is based on finding the link between the spoken intonation, the transmitted information in the given context, and the facial movements. First, we presented our facial model. We also enumerated and differentiated facial movements due to emotion or due to conversation. We look more particularly on the coarticulation problem where we examine how the action of a muscle is affected by temporal and spatial context. Currently we are working on the rules that coordinate these various facial motions with the intonation. Indeed, while a substantial number of these relations have been studied and described, many more remain to be investigated. We offer a tool to analyze, manipulate and integrate these different channels of communication and to facilitate the further research of human communicative faculties via animation.

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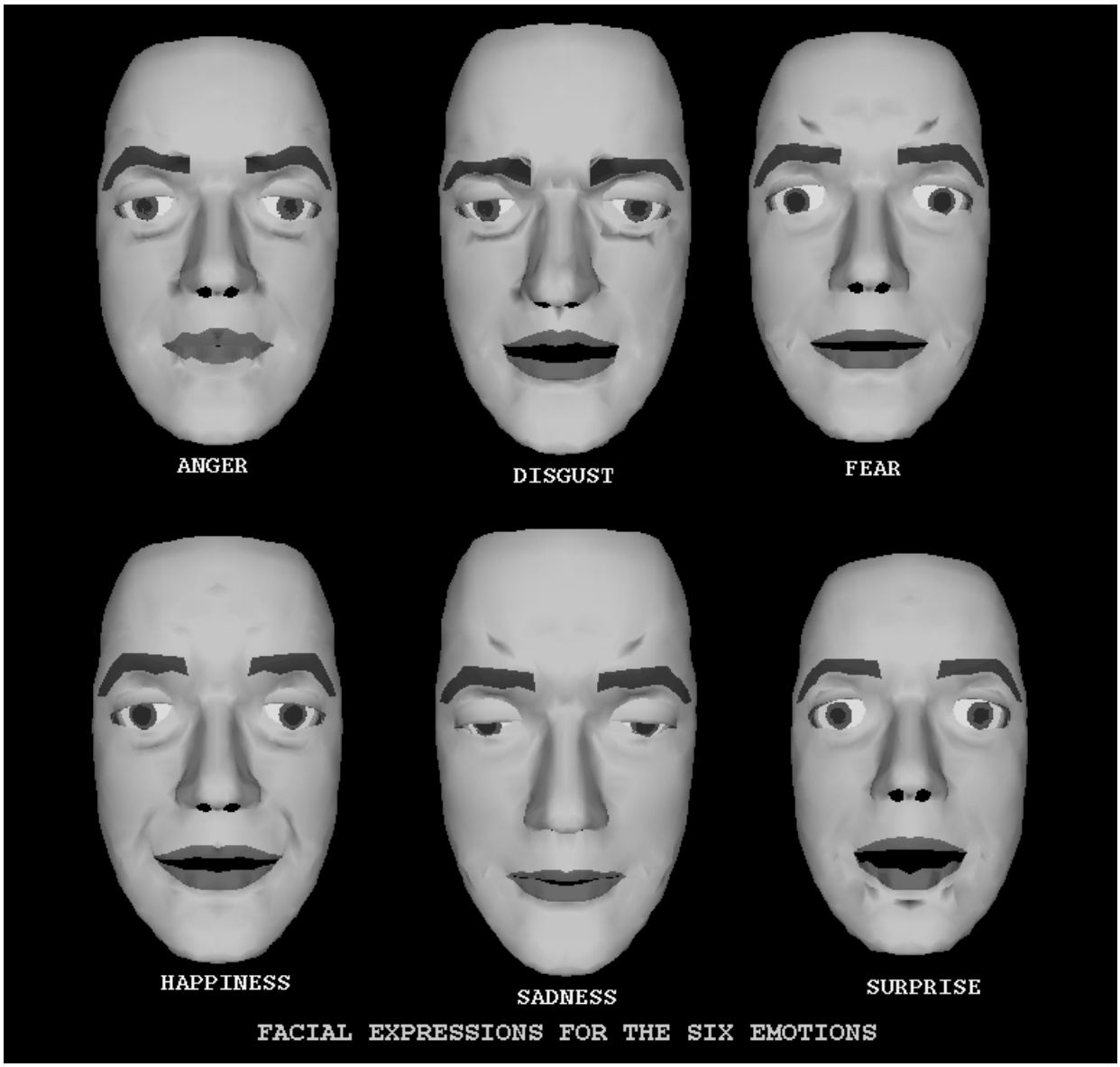

Figure 1: Facial Expressions for the Six Emotions

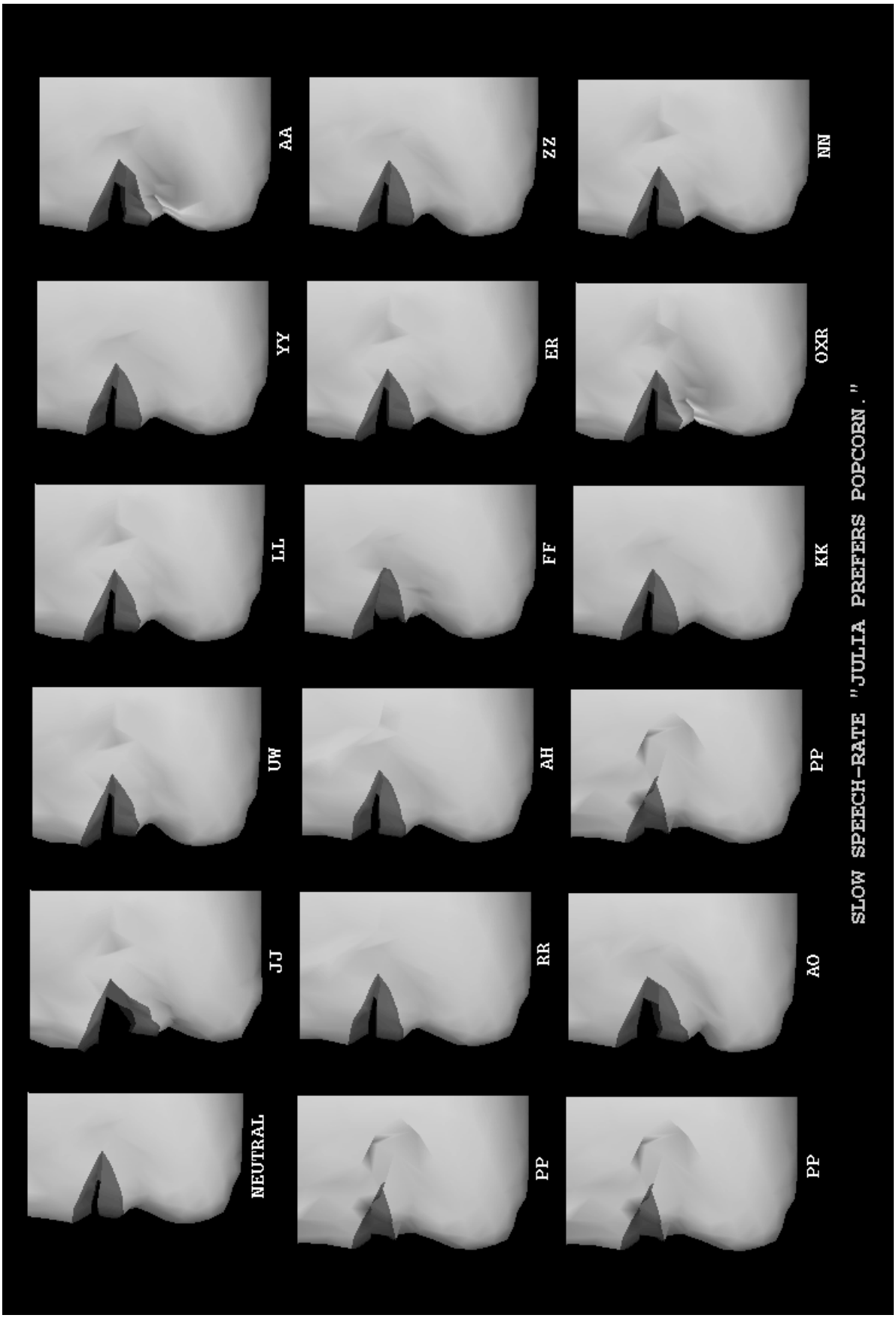

Figure 2: Lip Shapes for 'Julia prefers popcorn' with Slow Speech-rate

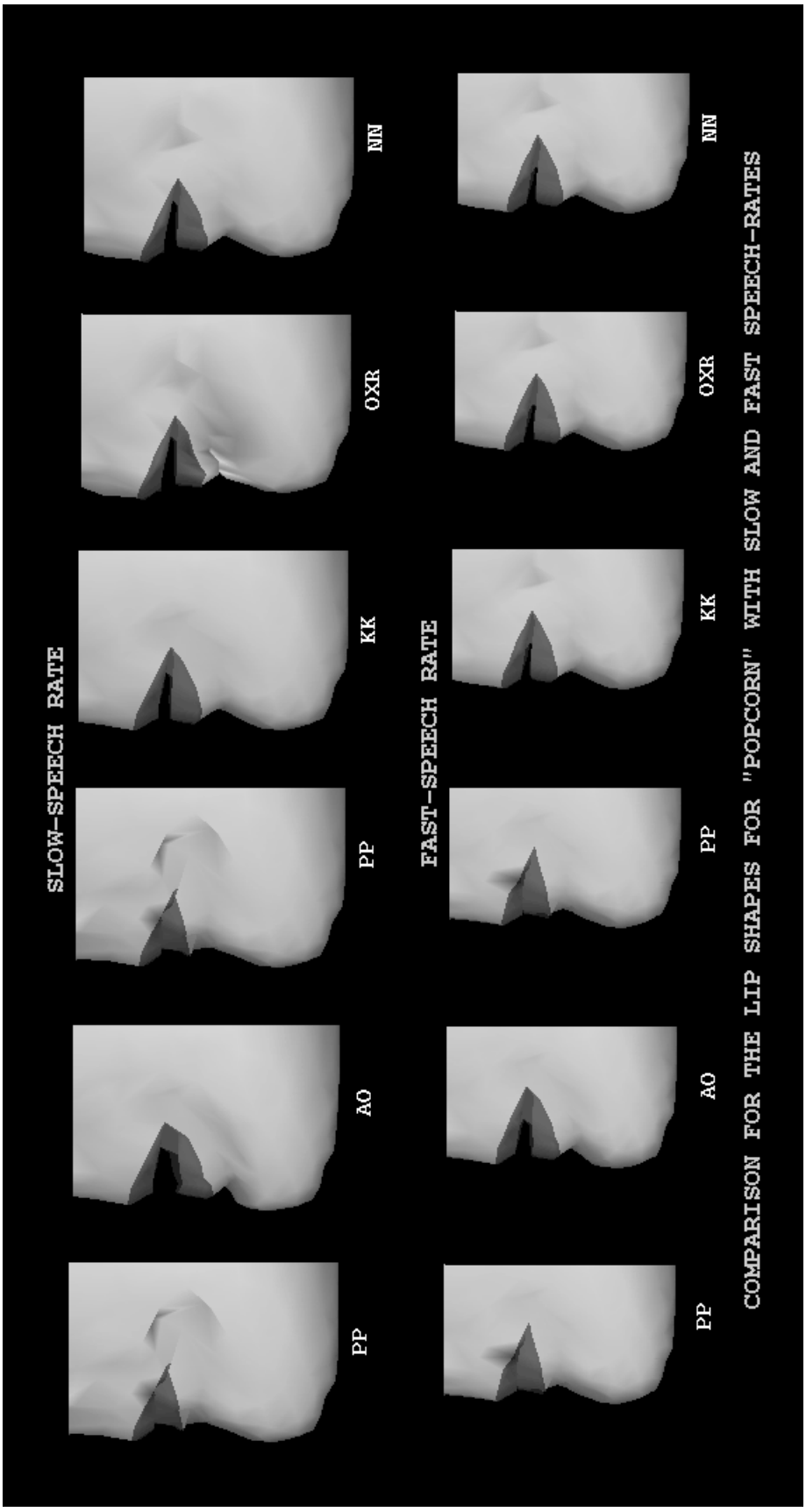

Figure 3: Comparison of the Lip Shapes for 'popcorn' with Fast and Slow Speech-rate

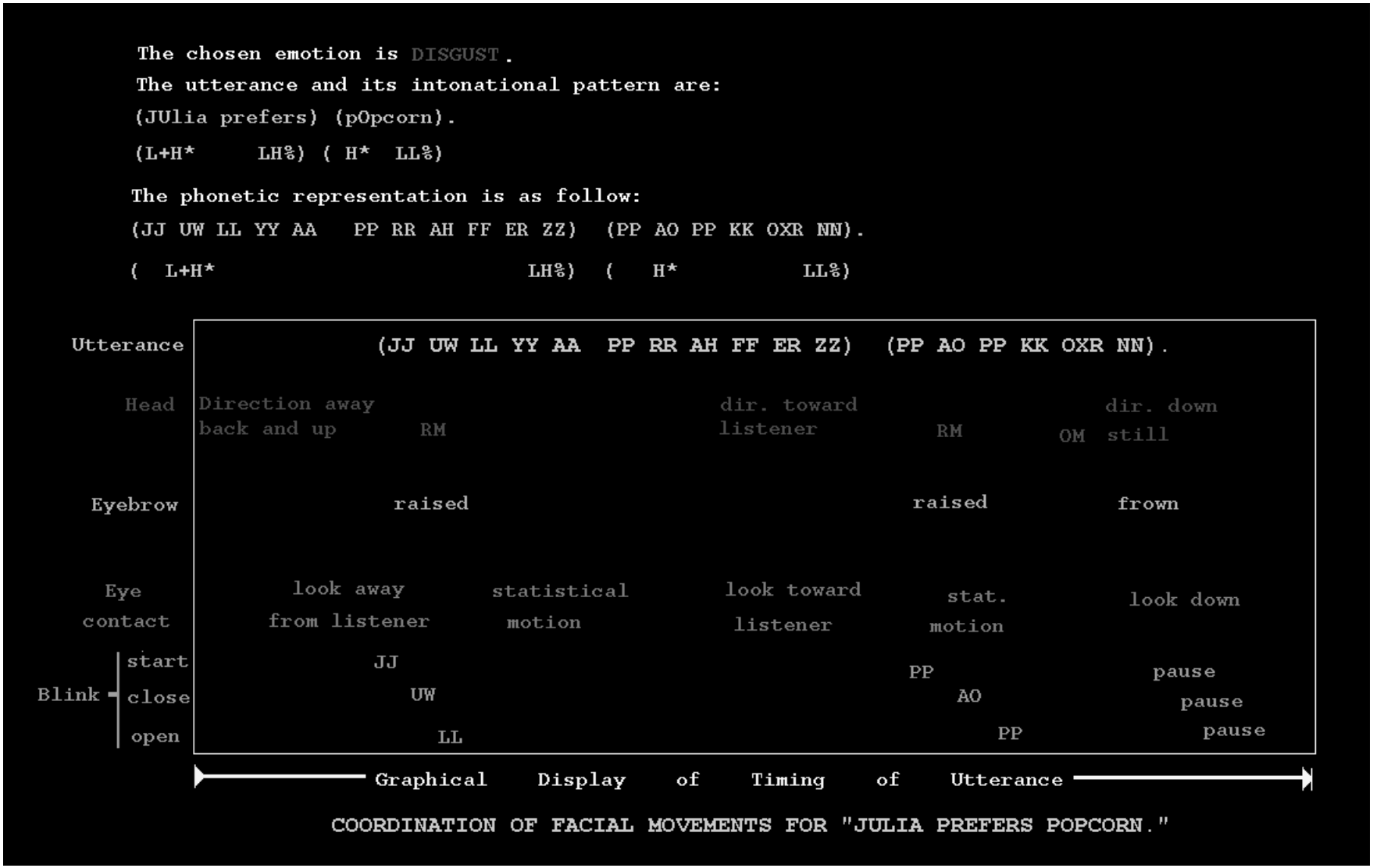

Figure 4: Coordination of Facial Movements for the example 'Julia prefers popcorn'