# Animated Interactive Fiction: Storytelling by a Conversational Virtual Actor

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## Abstract

*This paper presents an architecture for interactive storytelling using state-of-the-art-technology in natural language processing, speech synthesis and 3D-character animation. A conversational 3D-character is used to tell nonlinear stories interactively. Our research focuses on multimodal conversation that combines verbal-vocal with nonverbal-nonvocal natural language. We present a framework for synchronizing speech with facial movements, gesture and body posture by combining findings from linguistics and psychology. The interaction process incorporates the parsing of a textual natural language utterance, the emotion-based triggering of a textual response and its vocal and visual performance - speech synthesis linked with lip-synchronous generation of facial expressions and gestures.*

*Keywords: virtual actor, natural language processing, real-time 3D-character animation, autonomous agents, facial animation, nonverbal communication, nonlinear storytelling.*

## 1 Introduction

Autonomous 3D-characters have been developed for two purposes: In multimodal user interfaces [1] [2] the computer becomes an anthropomorphic personal assistant. The second purpose is entertainment. Synthetic characters inhabit virtual worlds and interact with each other and the user [3] [4].

Nonlinear storytelling using conversational 3D-characters is a new approach to interactive entertainment. Our framework merges *autonomous 3D-character animation* with *nonlinear storytelling* incorporating selected principles from *computer linguistics* and *psychology*.

The characteristics of the system presented in this paper are:

- The interactive story emerges from the semi-autonomous behaviour of a virtual actor during the dialogue with a user. The autonomy is constrained by a nonlinear plot structure that is extended by a chatting mode.
- The virtual storyteller acts the way he does because he follows a script. There are however degrees of freedom in choosing different paths in the nonlinear story structure and taking minor detours while chatting about specific topics.
- The plot structure, chat topics and the 3D-character are designed by professional authors.
- The user participates as the interlocutor of the semi-autonomous character that tells the story.
- The user is guided by the utterances of the virtual actor in the dialogue.

A powerful approach to the problem of animation is demonstrated in [5] by providing tools for scripting complex behaviours. However, coming up with the appropriate communicative behaviours and synchronizing them with an actual conversation still remains a challenge. This paper focuses on the conjunction of verbal natural languages with nonverbal behaviour in the context of storytelling using an *autonomous 3D-character*. The intermediate textual representation is enacted by the 3D-character using both verbal-vocal and nonverbal-nonvocal natural language. The spoken language output is produced by a voice synthesizer. The nonverbal behaviour comprises lip-movements, facial expressions, gesture and body posture.

This concept has been designed for future *interactive television*. Virtual actors performing live in television shows should be able to interact autonomously with individuals of the target group. The scenario includes an author writing stories that are produced and performed automatically by an autonomous 3D-character during the conversation with the user. At periodic intervals (e.g. each week) a new story is written by one or more authors.

We implemented our ideas in a protype system called AIF-system (Animated Interactive Fiction). The AIF-system works with a conversational cactus (figure 7) who tells "Alice's Adventures in Wonderland" [6]. The 3D-character has been designed for live performances in german youth television. The story has been rewritten as an *interactive dialogue script* by the authors focusing on representing nonlinear narrative structures[1] in the hypertextual structure of the dialogue script.

This paper is organized as follows: Chapter 2 describes the way our approach combines principles of hypertext fiction with techniques from chat programs. In chapter 3 the story is integrated in a framework for audiovisual performance of individual sections of text using the virtual actors verbal and nonverbal communication skills. Chapter 4 describes the implementation of the AIF-system. An overview of future directions is shown in chapter 5. Chapter 6 gives a summary and concluding remarks.

## 2 Textbased Human Computer Conversation: Chatting in Hypertext

Most *natural language parsing systems* have been developed for special purposes such as natural language interfaces for databases inquiries (e.g. railway information desks, question answering systems). Dialogue systems [7] [8] have been developed as descendants of the ELIZA program [9]. These *chatterbots* use word pattern matching and answer templates for conducting dialogues about a special domain, which remains unchanged throughout the conversation. The textbased part of our approach to natural language interaction with virtual actors combines methods used by chatterbots with the principles of hypertext fiction.

In *hypertext fiction*, links between paragraphs offer the user freedom to choose between different paths, in most systems by clicking on marked words or icons. Some of them incorporate a keyword parser that matches keywords against the user input [10]. A successful match displays the text of the connected paragraph. The story structures have different degrees of nonlinearities. The approach of writing hypertext scripts allows the addition of high quality literature to natural language interaction with autonomous virtual actors.

### 2.1 Expectation Driven Natural Language Analysis

Nonlinear storytelling systems based on hypertext implicitly make use of changing story levels. The story level has an impact on the word patterns that are to be matched against the input string and the possible hyperlinks that are activated by a matched word pattern. Each story level has its own set of word pattern. The principle of word pattern matching has been introduced by [9] and adopted by [7] [8]. This dynamic adaptation of word patterns caused by the advancing story level extends the principle of word pattern matching by an *expectation based parsing algorithm*. In the highest level of our analysis we consider only word patterns that are likely to be used by a potential user. The search space is reduced to context-relevant utterances. Using an efficient hashing algorithm the production of an appropriate answer is not time critical.

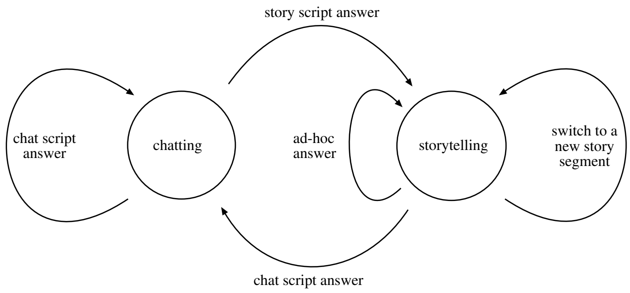


Figure 1: Two global states of the AIF-system: chatting and storytelling.

### 2.2 Strategy for Natural Language Understanding

It is the author's task to write an *interactive dialogue script*. An interactive dialogue script contains a dialogue with the part of one of the interlocutors being unknown during script writing. The unknown role is anticipated by the author and fulfilled by the recipient of the story at run-time. The author writes an utterance for his character and anticipates possible reactions. Assuming that the recipient is immersed in the story by the convincing nature of the character they will react in one of the anticipated ways. The author classifies the anticipated answers into semantic categories and identifies a common word pattern (the invariant part) for each category. The author has to discover what the recipient of the story (a typical member of the target group) is likely to ask or say. The key is to identify a common word pattern for each group of utterances that should lead to the same system reaction. By doing this he unifies a variety of possible user utterances to one semantic representa-

[1] The written version of Carrolls fary tail are based on conversations of Lewis Carroll with his niece Alice, a nonliear dialogue structure.

tion. This approach of identifying the invariant part of a group of utterances dealing with the same meaning has been termed *computational behaviourism* by [11]. The invariant part of a semantic category is the word pattern used for analyzing the user's textual input. The author specifies a reaction rule for each semantic category.

If the user does not react with an anticipated utterance we consider small *chatting detours* as an appropriate handling mechanism.

### 2.3 Storytelling with minor chatting detours

Our approach involves a script interface. This enables an author to write an interactive dialogue script without having specific programming skills. There are two kinds of scripts - one for *nonlinear story structures* and the second for *chatting*. In case of a communicational mismatch in the process of interactive narration, the virtual actor starts a small chatting sequence to bring the user back to the story context (figure 1).

The program performs a prewritten script by a professional author, who writes both the story's macro structure (narrative structure) and its micro structure (contents of single story segments). This allows interactive fiction to be of literary quality. Stories for this framework should have a nonlinear narrative structure.

### 2.4 Emotion-based Control of Text Generation and Animation

We propose the implementation of an emotional state E that influences the performance of a story segment. The emotional state E should be created out of the path taken in the nonlinear story structure. The psychologist Izard [12] identified nine basic emotions (interest, joy, surprise, sorrow, anger, disgust, contempt, fear, and shame). All emotional nuances can be represented by combinations of these basic emotions. While writing the story segment the author specifies a numerical value $imp_i$ for each basic emotion $i$ that is provoked by the presented narrative situation. Each emotional value specified for a story segment is a contributing factor in the calculation of the virtual actor's emotional state E as he tells that story segment. The actual intensity $em_i$ of basic emotion $i$ is computed at run-time by summing up all emotional impulses $imp_i$ of previously activated segments:

$$em_i = \sum_{j=0}^{n} g(j, imp_i) \qquad \forall em_i \in E, j \in \mathbb{N}_0^+$$

$j$ specifies the temporal distance between the previously activated segment and the current segment measured by the number of intervening segments. n is the number of basic emotions. $g(j, imp_i)$ delivers the contribution to $em_i$ of an impulse $imp_i$ from a distance of j segments. With a greater distance the contribution should be reduced:

$$g(j, imp_i) > g(k, imp_i) \qquad \forall j, k \in \{\mathbb{N}_0^+ | j < k \leq n\}$$

The emotional state E influences the way in which the storytelling character presents the content of the story segment in terms of text, speech, facial expression, gesture and posture.

## 3 Synchronizing verbal and nonverbal behaviour

We study animation of autonomous 3D-characters from the point of view of the animator. This means that we formalize the rules which an animator uses implicitly while telling a story by means of a 3D-character using both verbal and nonverbal language.

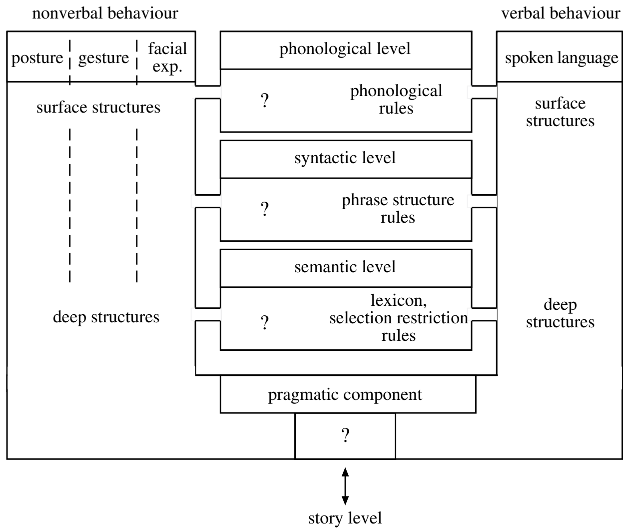


Figure 2: A theoretical model for establishing synchronization rules for verbal-vocal language and nonverbal behaviour.

### 3.1 Nonverbal Behaviour

The rules of verbal natural language are motivated by implicit syntactic and semantic agreements of a cultural group. Nonverbal behaviour is much more bound to and influenced by personal traits instead. Current research in communication psychology [13] tries to discover that part of nonverbal behaviour which is independent of personality. So far rules for the implicit psychological semantics of nonverbal behaviour have not been formulated. Although there are gestures and facial expressions that are understood nationally or worldwide (waving hello, a happy/sad face) most subtle semantic nuances of nonverbal behaviour are only interpreted in the right way if one knows the expressing person quite well. For cartoon characters idiosyncratic communicational signals are especially important. Some of these signals are modelled on animal behaviour (e.g. ear wiggling), others are purely fantasized by the cartoonist or animator. Our approach to autonomous animation of virtual actors views the characters as a whole: commonly understood nonverbal behaviour is combined with behaviour peculiar to the character. We aim to formalize the rules an animator uses implicitly during the process of animating a character.

### 3.2 Multimodal Dialogue

Verbal and nonverbal natural languages have been studied in linguistics and psychology. Verbal languages have evolved as the preferred intracultural communication medium. The use of the analytical levels *syntax*, *semantics* and *pragmatics* proposed by [14] are common in linguistics. Computer linguists use the sophisticated grammatical and lexical rules for developing natural language understanding and generation systems. Many psychologists, e.g. [15], [16], [17], use (explicitly or implicitly) the same analytical levels for the study of nonverbal behaviour. Our approach to autonomous character animation is based on the assumption that verbal and nonverbal behaviour can be synchronized on phonological, syntactic, semantic and pragmatic levels.

Chomsky's theory of transformational grammars distinguishes between *surface structure* and *deep structure* of sentences. The latter contains the information necessary for interpreting the sentence correctly. The surface structure defines the right word order of a sentence. *Transformational rules* map the surface structures bidirectionally onto the deep structures. Following Chomsky's theory of generative transformational grammars [18], figure 2 shows a theoretical model for establishing rules for the synchronization of speech with nonverbal behaviour. The pragmatic component deals with story segment, hypertextual links, mental concepts, ideas, etc. Confronted with new input from its environment (e.g. the user) the character selects a story segment with appropriate structures of verbal and nonverbal behaviour. For performing spoken language, gesture and facial movements, these deep structures have to be transformed into synchronized surface structures - the audiovisual output perceived by the user. This synchronization is performed on phonological, syntactic, semantic and pragmatic levels.

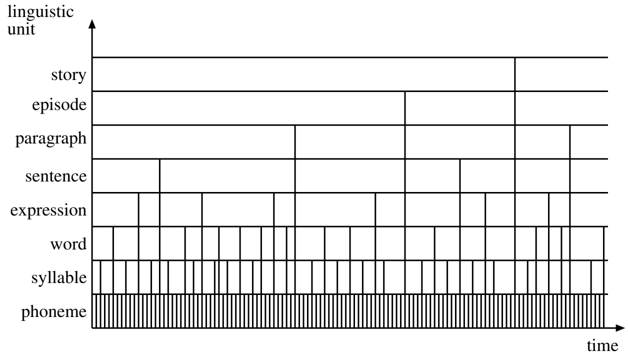


Figure 3: Linguistic units with different cycles of change.

The question marks in figure 2 mark our research focus. Known strategies for natural language processing have to be linked to their equivalents for gesture and facial expression. Those linkage rules involve decisions such as "Should a semantic content be expressed verbally, use gesture or facial expression, or a combination of these?"; "Should meaningful words be stressed vocally and accentuated by gestures?", etc. Some rules are known from disciplines such as phonology, psychology, and cartoon animation. Some examples taken from [17]: raising the eyebrows or nodding the head on an accented syllable or a pause (syntactic functions); wrinkling the nose while talking about something disgusting or smiling while remembering a happy event can substitute for a word or refer to an emotion (semantic functions). The pragmatic level unifies body language with verbal natural language and connects the communication aspect with the story level. The emotional state E proposed in this paper synchronizes the nonverbal behaviour of the 3D-character with the content of the spoken language.

### 3.3 Synchronizing Speech with Gesture and Facial Expression

The first step for establishing a rule system for synchronized verbal and nonverbal behaviour of autonomous 3D-characters is to study the translation

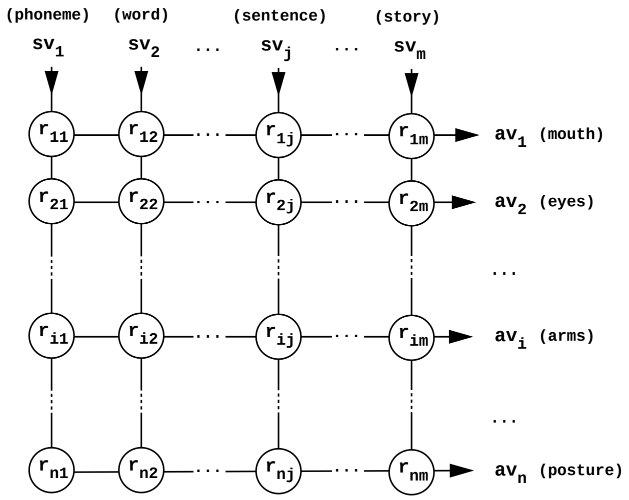


Figure 4: Translation system from text to animated speech.

from the textual representation into vocal language and nonverbal behaviour. We assume that body movements and voice intonation are determined at each point of time by the current phoneme, syllable, morpheme, word, linguistic expression, sentence, paragraph, episode, and story. Each linguistic unit influences verbal and nonverbal surface structure to a different degree. The linguistic units change their value at different frequencies (figure 3). The challenge is to formalize the influence of each linguistic unit on each physical movement of the character and to discover linkages between these influences that can be mathematically defined. Figure 4 shows these translation from text to animated speech. We implement lexica that assign animation rules to each control variable $sv_j$. These rules translate the input values into abstract values for $rule_{ij}$. The animation rule for $sv_{phoneme}$ = "a", e.g., is:

$$rule_{mouth,phoneme} = \text{“}open\text{''}$$
$$rule_{i,phoneme} = \text{“}neutral\text{''}\ \forall i \in \{\mathbb{N}^+ | av_i \neq mouth\}$$

Each animation variable $av_i$ interpretes the abstract value of the animation rule $rule_{ij}$ individually. If the value $r_{ij}$ is connected additively, the $rule_{ij}$ = "neutral" is translated into $r_{ij} = 0$. If the connecting operation is multiplication $r_{ij} = 1$ would be appropriate. The animation function for the mouth opening is e.g.:

$$av_{mouth} = r_{mouth,phoneme} * (r_{mouth,syllable} + r_{mouth,word} + r_{mouth,episode} + r_{mouth,story})$$

# 4 Current Implementation

The architecture of the current implementation (figure 6) comprises three modules. The *text module* translates the textual input into an output string. The *animation module* generates appropriate movements and synchronizes the *visualization module* and the *voice synthesizer* "Hadifix" [19].

## 4.1 Text Module

Viewed as a black box the text module seems like most systems for hyperfiction or chatterbots: a small textfield for the user input and a larger text area for output. The text module in itself can not show the emotional state that is being computed after each interaction. The representation of emotions is the task of the animation and visualization modules on a later processing level. The text module uses the emotions to choose between different ways of expressing the content of a paragraph textually.

The *script parser* of the AIF-System creates a nested structure of objects containing the textual strings and word patterns specified in the parsed scripts.

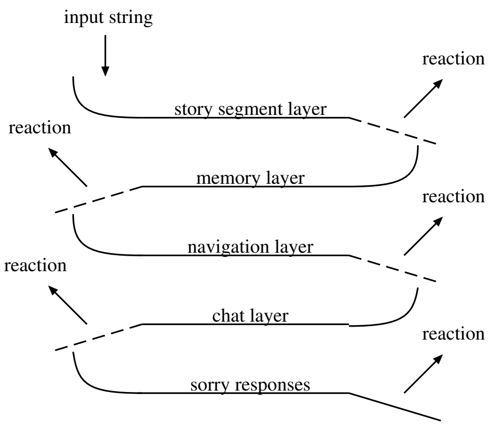


Figure 5: Miniexperts organized in prioritized layers.

The object structure is organized so that a group of objects form a "miniexpert", a small expert system for a special limited knowledge domain of the corresponding paragraph. These miniexperts are organized in prioritized layers (figure 5). The principle of a prioritized layer system of miniexperts is known from [7].

The *story segment layer* tries to find a matching word pattern and its corresponding segment in the current context of the story, as described above. AIF

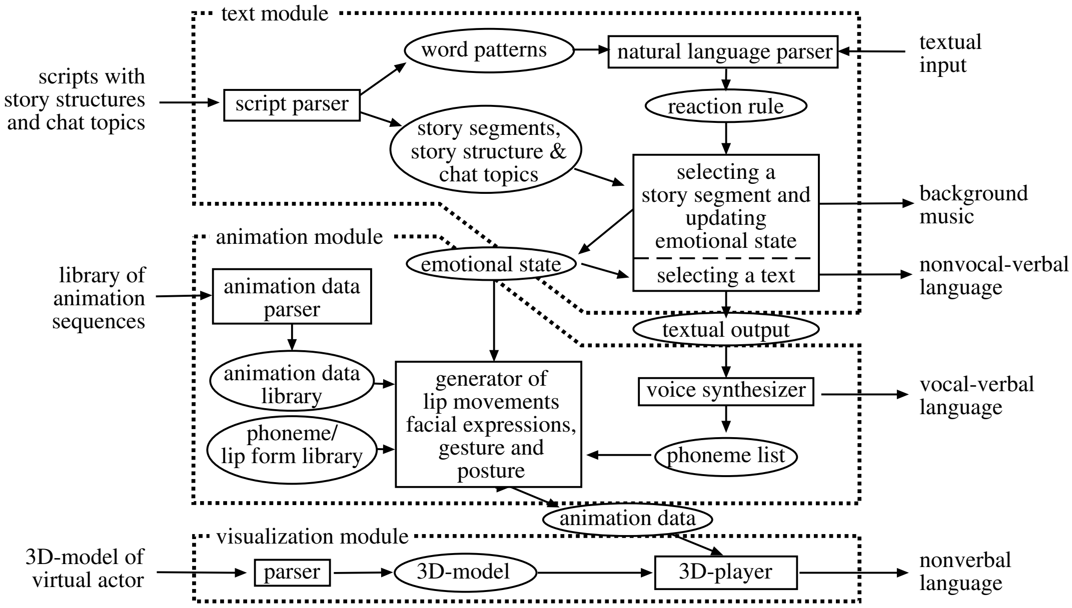


Figure 6: Architecture of the AIF-system.

analyses the textual input in the context of the current paragraph. Each paragraph has its own set of keywords and word patterns that are matched against the input string. *Priority stacks* are used in case of multiple matches. A successful match delivers a *reaction rule* that specifies one of the following:

(a) a simple text (spontaneous remark, additional explanations, etc.) that is recited without switching to a new segment,

(b) a text template that is filled with appropriate parts of the user's input string,

(c) a label that activates a new story segment, or

(d) a sequence of labels that invokes the corresponding segments without expecting an utterance in between.

The simple text contains for example less important but entertaining remarks or additional information referring to the current paragraph. It does not link to a new segment, nor does it update the emotional state E; the text is simply displayed. Reaction rule (d) activates the specified segments without waiting for a reaction from the user. Each activation has the same effect as reaction rule (c). As a new segment is activated, the system adds the emotional impulses $imp_i$ of the new situation to the emotions that remain from the previous segments. The current emotional state E is computed by a weighted summing of all experienced emotions. The older the emotions are the less they contribute to the emotional state. For each basic emotion a numerical value is computed seperately using $g(j) = e^{-j}$:

$$em_i = \sum_{j=0}^{n} imp_i * e^{-j} \qquad \forall em_i \in E, j \geq 0$$

The emotion with the highest value determines the output text that is given together with the emotional state E to the animation module.

If the analysis in the context of the story segment fails, the input string is passed on to the *memory layer*. Here the path of previously activated segments is searched. The word patterns used for matching in the memory layer are different from the ones in the story layer. They are taken from different word pattern lexica and have different effects in the case of a positive match: the corresponding segment of a matched word pattern in the memory layer is not activated, a short summary of this segment is given and the activation stays at the current segment.

If the memory layer can not match the input string, it is passed on to the *navigation layer* that reacts on utterances intended as commands e.g. "tell the whole story from the beginning", "repeat the last paragraph" or simply "go on".

A matching word pattern in the *chat layer* leads to a switch to chatting mode (figure 1). In this case the analysis of the next interaction cycle does not start with the story layer but directly with the chat layer.

The system stays in this mode randomly for n interaction cycles. The value of n depends on the mood of the character. Frequent values are "n=2", "n=3" and "n=4".

A synonym lexicon is used to improve the method of word pattern matching. Furthermore the generation of answer sentences from templates requires word transformations to meet grammatical rules of the german language.

### 4.2 Animation Module

The text is synthesized and the spoken output is written to an audiofile. The sequence of phonemes is used to add the corresponding lipforms to the facial expressions that are generated together with body movements using libraries of animation data. The generator is based on the translation system shown in figure 4.

The generation of body movements is based on preproduced animation sequences stored in an *animation data library.* The methods and tools used to produce animation sequences for the library involve real-time recording with datagloves, a motion-capture-system and a modelling editor. This method of real time animation of 3D-characters has been developed by [20] [21] [22] for the purpose of live performances.

The movement generation module assembles an appropriate animation putting together sequences taken from the animation data library. The assembly rules stem from semantic and syntactic synchronization levels (figure 2). In the resulting sequence, adjustments are made to specific regions of the 3D-model to meet criteria of the phonological level, like synchronous lip movements or sudden movements of the hands. Emotional facial expressions are produced by a subsystem developed by [23].

The animation data produced by the animation module is used by the visualization module to animate the figure on the display. Both modules communicate by means of a shared memory area.

### 4.3 Visualization Module

The visualization module has read the data of the three-dimensional static appearance of the virtual actor during the start-up-phase of the AIF-system. The 3D-character used in the prototype system has 36 motion effectors (e.g. head up, mouth open, left arm up, etc.) that are controlled by the animation data. Each value is updated 25 times per second. A motion effector influences a group of triangles on the figures surface mesh, that defines the shape in three dimensional space. The mapping between 3D-data-points and each motion effector has been defined by the animator while designing the figure.

The virtual actor used in the current implementation is composed of approximately 4000 polygons. It is controlled via 36 motion effectors that in turn are connected to 178 basic expressions. Figure 7 shows the 3D-character of the current implementation - the conversational cactus telling the story of "Alice's Adventures in Wonderland".

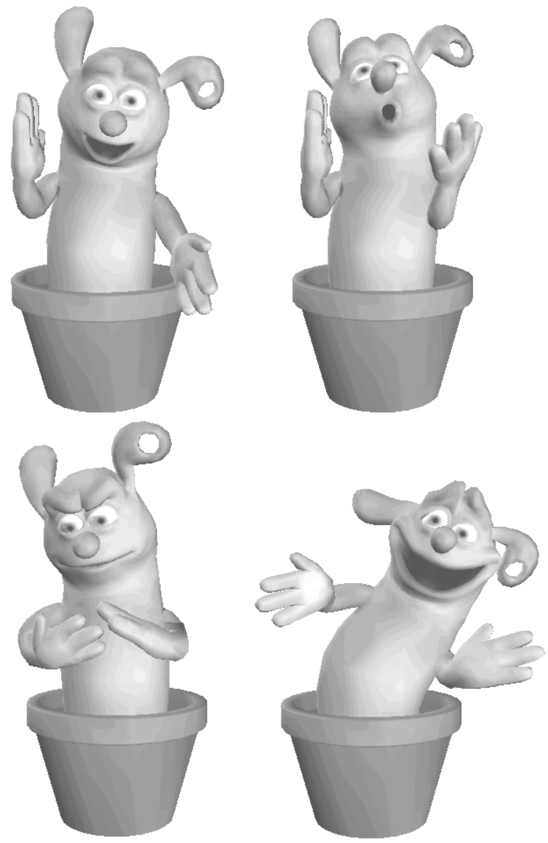

Figure 7: Selected nonverbal behaviour of the conversational cactus.

## 5 Future Directions

We are continuously extending the script system and analyzing the degree of complexity required for improved conversational abilities. One question is to what extent a highly complex script system can be maintained by one author. Known Strategies from computer supported cooperative work (CSCW) can be used for distributed script authoring in teams of writers. Current work involves the development of graphical tools that enable the author to write nonlinear story scripts more easily. These should incorporate facilities for grouping nodes and distinguishing between macro and micro structures in the linkage on different levels. We will try to feed the virtual actor with more than one story for developing strategies for domain switching.

The semantic classification into categories with a common invariant part is to be replaced by automated unification. A syntactic and semantic analysis that translates the textual surface structure into a meaning representation will be deployed as the unification algorithm. [24] is considered to be appropriate for the development of the meaning representation language.

The unknown implicit rules of an animator are formalized heuristically as yet. The *analytic approach* is based on the analysis of motion-frequencies. The changes of different linguistic units occur at different periodic intervals (figure 3). The influences of each linguistic unit on each motion effector can be separated using multi-resolution filtering methods and fourier transformation. For each motion effector the animator intuitively produces a text-synchronous animation curve. A fourier transformation of the data allows the separation of movements that stem from periodical changes occuring at different frequencies. The reverse fourier transformation delivers functional descriptions of influences that change at the specified separation frequencies. The frequencies with which a phoneme, syllable, word, etc. change are chosen as separation frequencies. The functional descriptions that are delivered by the reverse fourier transformation can be assigned to the linguistic units.

## 6 Summary and Conclusions

In our work, selected principles of natural language processing and hypertext fiction have been combined with methods from 3D-character animation to form a framework for interactive storytelling. Rules for the synchronization of verbal and nonverbal behaviour on phonological, syntactic, semantic and pragmatic levels have been implemented in the AIF-system. On the pragmatic level the character's emotional state connects the synchronized speech and body movements with the story level. The emotional state is influenced by previously experienced situations and adapts the behaviour of the virtual actor to the current path in the nonlinear story structure. The story is presented in a multimodal dialogue. The utterances of the user influence the path in the nonlinear story structure at each point of interaction. This approach allows the active participation of the user in the storytelling process.

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