Elckerlyc goes Mobile
Enabling Technology for ECAs in Mobile Applications

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***Abstract*—The fast growth of computational resources and speech technology available on mobile devices makes it possible for users of these devices to interact with service systems through natural dialogue. These systems are sometimes perceived as social agents and presented by means of an animated embodied conversational agent (ECA). To take the full advantage of the power of ECAs in service systems, it is important to support real-time, online and responsive interaction with the system through the ECA. The design of responsive animated conversational agents is a daunting task. Elckerlyc is a model-based platform for the specification and animation of synchronised multimodal responsive animated agents. This paper presents a new light-weight PictureEngine that allows this platform to embed an ECA in the user interface of mobile applications. The ECA can be specified by using the behavior markup language (BML). An application and user evaluations of Elckerlyc and the PictureEngine in a mobile embedded digital coach is presented.**

***Keywords*-Mobile User Interfaces**

I. Introduction

Advances in user interface technology — speech recognition, speech synthesis and screen capacities — allow more and more people to engage in spoken interaction with services on their mobile phones. Examples of these services are intelligent personal assistants in search applications, persuasive systems or characters in games. It is well known from user studies that the use of a talking head or an embodied conversational agent (ECA) has a positive effect on user experience when using these kind of services [1].

The presentation of a service agent by means of a persona supports the idea of the computer as a social actor. Research has shown that animation of human-like social behaviours and expressions by means of a virtual human or embodied conversational agent strengthens the impression that the agent is present and engaged in the interaction. In human-human conversations the one who has the speaker role is monitoring his addressees while speaking. Listeners give backchannels, short comments, and may also interrupt the speaker. By his gaze behaviour the speaker shows his interest with the addressee. By adjusting or stopping his speech he shows being responsive to the listeners comments and that he is really engaged in the conversation. Gaze behaviour in conversations is important for interaction management, in particular for signaling that one wants to have the floor, that the speaker wants to keep the floor or is willing to yield the floor. Expressions of emotion are prime indicators of engagement in what is going on in the conversation [2]. In designing virtual humans that are able to show these social signals and responsiveness one needs well designed model-based specification languages and tools.

```
<bml id="bml1" xmlns:pe="http://hmi.ewi.utwente.nl/pictureengine"
   xmlns:bmlt="http://hmi.ewi.utwente.nl/bmlt">
    <pe:setImage filePath="/pictures/" fileName="neutral-open.png"
    layer="1" start="0" end="30.0" id="0"/>
    <speech id="s1" start="1.0">
        <text>
          Hello, my name is Brenda, I will be your coach for the coming weeks.
        </text>
    </speech>
    <speech id="s2" start="s1:end">
        <text>
          This text is synchronized through BML!
        </text>
    </speech>
    <face type="LEXICALIZED" lexeme="smile" id="smile1" start="s2:start" end="s2:end"/>
    <pe:addImage id="brows" filePath="/pictures/" fileName="brows-raised.png"
    layer="7" start="s2:start" end="s2:end"/>
    <bmlt:blinkemitter
       id="blinkemitter1" start="0" end="s4:end" range="1" avgwaitingtime="4"
    />
</bml>
```

Figure 1. An example of a BML specification for an ECA.

The SAIBA framework [3] provides a good starting point for designing interactive virtual humans. Its Behaviour Markup Language (BML) defines a specification of the form and relative timing of the behaviour (e.g. speech, facial expression, gesture) that a BML realizer should display on the embodiment of a virtual human. An example of a specification in BML can be found in figure 1. Elckerlyc is a state-of-the-art BML realizer. In [4] its mixed dynamics capabilities are described as well as its focus on continuous interaction, which makes it very suitable for virtual human applications requiring high responsiveness to the behaviour of the user.

The Elckerlyc platform can act as a back-end realizer for different embodiments, like physical robots or realistic 3D

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full kinematic virtual humans. Using a full 3D virtual human on a mobile phone is too heavy in terms of processing power and battery usage. To be able to use the Elckerlyc platform on a mobile phone a light-weight animation embodiment is needed. This paper presents the PictureEngine, a light-weight animation embodiment that enables our SAIBA-based BML realizer to be implemented and run on mobile applications. Section II describes the Elckerlyc platform in more detail. The PictureEngine will be discussed in Section III, the Android implementation of the platform and the PictureEngine in Section IV.

Research by e.g. Bickmore [1] showed that personification of the user interface of coaching systems can have positive effects on the effectiveness of the coaching program. Real-time animations do have a positive effect on the user experience. Compared to static pictures or prerecorded movies, real-time animations are able to react immediately to the user. Responsiveness increases the experience of engagement of the agent. In section V a personalised context-aware multi-device coaching application will be discussed. The coaching application makes use of the mobile Elckerlyc platform. The ECA developed for this application presents feedback from the digital coach by animated spoken interaction. We conclude with with a description future work on the development of the mobile embodied coach and user evaluations of a coaching application that is using the PictureEngine.

II. THE ELCKERLYC PLATFORM

In behaviour generation, at least two main aspects can be distinguished. The first aspect is the planning of the actions and movements as means to a certain goal that the agent intends to achieve. The second one is the actual detailed realisation of the verbal and non-verbal behaviours in terms of "embodiments" of the (graphical) virtual human - including the generation of the speech by a text-to-speech synthesizer. This distinction between intent planning, behaviour planning and behaviour realisation is the basis of the SAIBA[1] framework [5]. According to this framework the detailed behaviours are specified in the Behaviour Markup Language (BML)[6].

The Elckerlyc platform is a BML realizer for real-time generation of behaviours of virtual humans (VHs). The Elckerlyc platform has been described and compared with other BML behaviour realizers (for example EMBR [7] and Greta [8]) in various papers [9], [10], [4].

Dependent on the application and task that the intelligent system has, the virtual human presents for example the character of a tutor, an information assistant, or a conductor. The goal is to make these embodied conversational agents look like believable and convincing communicative partners while interacting with humans. This requires the generation and coordination of "natural" behaviours and expressions.

[1] www.mindmakers.org

Reidsma and Welbergen [10] discusses several features of the modular achitecture of Elckerlyc and relates each of them to a number of use requirements. A general overview of the Elckerlyc system can be found in Figure 2. The input of the Elckerlyc platform is a BML specification. "BML provides abstract behaviour elements to steer the behaviour of a virtual human. A BML realizer is free to make its own choices concerning how these abstract behaviours will be displayed on the embodiment. For example, in Elckerlyc, an abstract 'beat gesture' is by default mapped to a procedural animation from the Greta repertoire. The developer may want to map the same abstract behaviour to a different form, i.e., to a high quality motion captured gesture."[10]. Different Engines will handle their own parts of the behaviour specification and generate synchronised instructions for realising i.e. speech output, body gestures, postures and facial expression. The output of all the engines is displayed on one embodiment, like a realistic 3D full kinematic virtual human, the Nabaztag or a graphical 2D cartoon like picture animation. Figure 3 shows three types of embodiments supported by the Elckerlyc platform.

Not every embodiment is able to render all the behaviours that can be specified in BML. This depends on what the embodiment offers e.g. a robot that is not able to smile or a picture animation that lacks a picture showing the smiling face cannot render the requested smiling behaviour. The interface between the output of Elckerlyc and the embodiment occurs in a Binding. A Binding is an XML description to achieve a mapping from abstract BML behaviours to PlanUnits that determines how the behaviour will be displayed in the embodiment. Bindings can be customized by the application developer.

This paper discusses how these Bindings were exploit. A light-weight PictureEngine was developed that makes it possible to run Elckerlyc on mobile Android platforms. Elckerlyc allows for a transparent and adjustable mapping from BML to output behaviours (rather than the mostly hardcoded mappings in other realizers), and allows for easy integration of new modalities and embodiments, for example to control robotic embodiments, or full 3D embodiments. To run Elckerlyc on mobile platforms a light-weight PictureEngine was developed that allows rendering of behaviours and expressions using layering of pictures.

III. THE PICTUREENGINE

A realistic 3D full kinematic virtual human embodiment is not suitable for use on mobile devices for multiple reasons. Not only do such devices lack the processing power to render this kind of environment, but displaying a full scene including a full body ECA on the relatively small screen of a mobile device is quite impractical. The displayed size of

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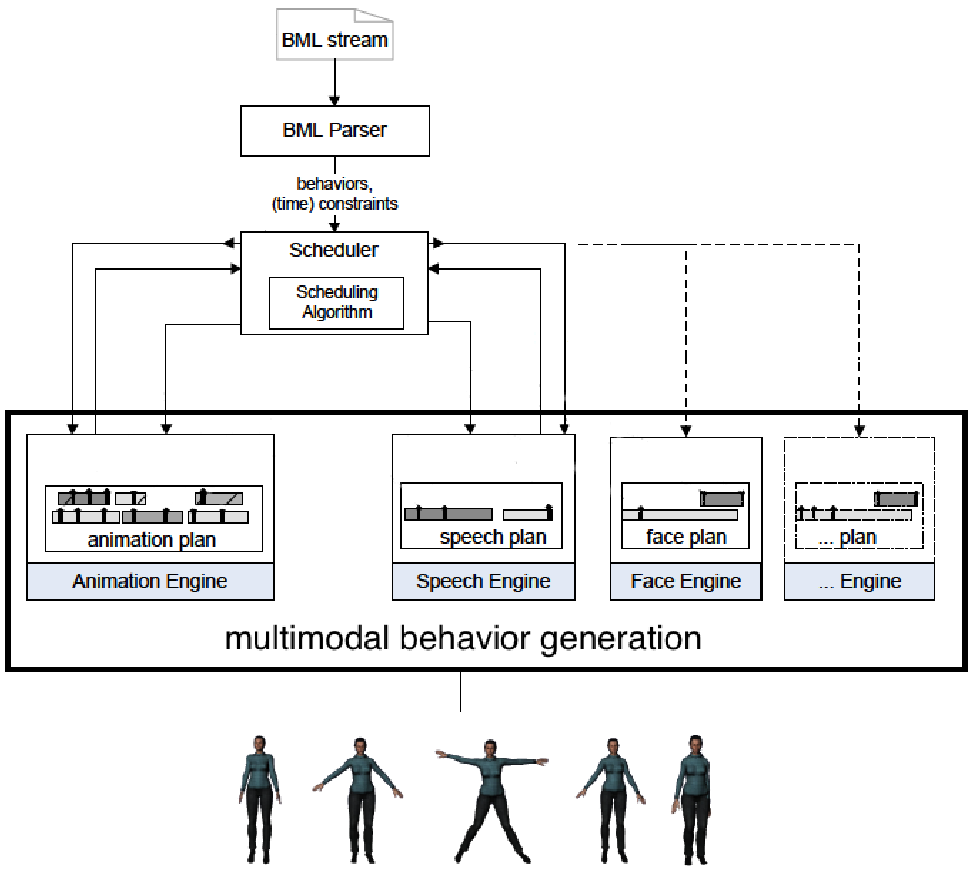


Figure 2. Overview of the Elckerlyc architecture. BML input is processed by the Elckerlyc system by different engines. The result is combined into one embodiement.

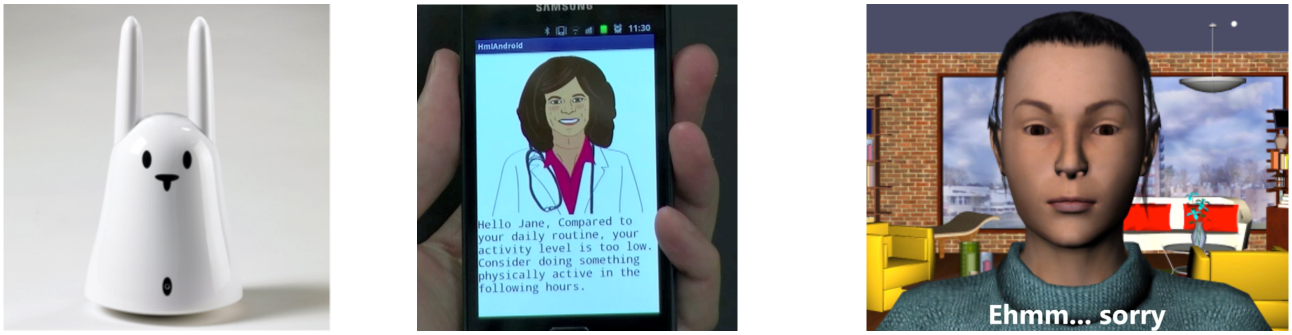
the ECA would make it so small that its expressions would hardly be visible. The high processing demands would also drain the device's battery quickly. In order to avoid all these problems, Elckerlyc uses a different graphical embodiment on the Android platform, the PictureEngine.

The PictureEngine is a lightweight graphical embodiment that uses a collection of 2D images in order to display the ECA. While having a 2D image embodiment does present some limitations, it also has its advantages. First of all, it has low demands in terms of processing and memory. It also allows for great variation in the design of ECAs. One could for example design a cartoon figure ECA, an ECA based on more lifelike illustrations, an ECA based on prerendered 3D images, or even an ECA based on photographic images of a real person. This section discusses the most important aspects of the PictureEngine.

A. Layers

In order to generate a dynamic ECA from a collection of images, the PictureEngine uses a layer-based approach. Different parts of the ECA are displayed on different layers of the final image, and can thus be in different states. For example, one layer may contain the eyes, while another contains the mouth. The base layer normally contains the ECA in a base state, meaning that when the ECA is in a neutral or passive state, the user sees only this base layer. That means that while each (facial) feature of the ECA does have its own layer, they are also present in the base layer. This means that the base layer contains for example a full face with a neutral expression, even though the eyes and mouth may have their own layers. There can also be layers containing features that are not visible in the base state, such as hands that only move into the frame when executing a gesture. By using this layer approach, different parts of the ECA can be manipulated independently and combined in order to generate different expressions. This also allows the ECA to do several (connected or unconnected) things at once, such as blink while also speaking and pointing at something.

As noted earlier, the layer approach does present some limitations. Because the features of the ECA are in separate layers, the base onto which these features are displayed



(a) The Nabaztag rabit (b) a 2D cartoon like picture animation (c) a realistic 3D full kinematic virtual human

Figure 3. Three types of embodiment used as back-end for the Elckerlyc platform

(usually a face, and possibly part of the body) is generally static. This means that any movement of the entire ECA poses a problem. When an ECA has facial features on different layers, the layered structure prevents it from moving around. This also applies to smaller movements such as nodding, shaking and tilting of the head. However, because the PictureEngine is designed to be used on smaller screens, the ECA will generally be displayed as a talking head, a closeup of a face covering most of the available screen space. In this kind of environment, having the ECA perform locomotion is already impractical and, since there is hardly any room for the ECA's environment to contain anything but itself, arguably unneccessary.

B. Animations

While single images may suffice for portraying expressions in many cases, there are other cases where an ECA simply has to display some motion in order to come across as believable. To make this possible, the PictureEngine also allows the use of animations instead of single images. These animations are defined by using a simple XML format that allows a number of images to be listed, together with the duration for which they are to be displayed. While these durations are specified in seconds, the nature of the BML scheduler allows the duration of animations to be adjusted according to the BML code that is being realised, causing the animation to play faster or slower depending on the timespan determined by the scheduler.

These animation XML files have an additional feature that provides an advantage over using an already established format for image animations: the possibility to include synchronization information in the animation specification. This allows a synchronization point to be included in the specification between any two frames of an animation. These synchronization points are available for use in the main BML code. In this way, it is possible to e.g. synchronize the stroke of a beat gesture animation with a certain word within a speech element.

```
<PictureUnitSpec type="face">
    <constraints>
        <constraint name="type" value="LEXICALIZED"/>
        <constraint name="lexeme" value="smile"/>
    </constraints>
    <parametermap>
    </parametermap>
    <parameterdefaults>
        <parameterdefault name="filePath" value="animations/"/>
        <parameterdefault name="fileName" value="smile.xml"/>
        <parameterdefault name="layer" value="8"/>
    </parameterdefaults>
    <PictureUnit type="AddAnimationXMLPU"/>
</PictureUnitSpec>
```

Figure 4. PictureBinding entry for a smile.

C. PictureBinding

Like other Elckerlyc embodiment engines, the PictureEngine uses a Binding. This PictureBinding allows a combination of a BML behaviour class and (optionally) several constraints to be mapped to a certain PictureUnit (i.e. an image or animation). It is possible to include anywhere from zero constraints to all the constraints defined for the corresponding BML behaviour type. This allows the designer of a PictureEngine ECA to refine those behaviours that are most relevant to the ECA, and implement any others in a more general fashion.

The actual PictureBinding itself is defined in an XML file containing the behaviour classes and constraints and the PictureUnits and parameters they are to be mapped onto (see Figure 4 for an example). The accessibility of this format allows an ECA to be designed or modified by someone who does not have knowledge of the inner workings of Elckerlyc. Only knowledge of BML and the available PictureUnits and their parameters is required to be able to build a complete PictureBinding.

D. Lipsync

In order to visually display the fact that the ECA is speaking, the PictureEngine provides a rudimentary lipsync facility. This lipsync feature is implemented in the same way as the lipsync provided by the default AnimationEngine.

However, where the AnimationEngine provides a full mapping from visemes to animation units, the PictureEngine lipsync currently does not make use of such a mapping (although it could be added in the future). In its current state the lipsync allows a single animation to be specified which is played whenever the ECA is speaking. This animation is repeated for the number of times it fits into the duration of the speech unit (and slightly adjusted so that the amount of repetitions becomes a round number).

IV. ANDROID IMPLEMENTATION

Since the Elckerlyc platform is implemented almost entirely in Java, all of its core elements run on Android without any modification. However, since Android has its own environment for visual and audio output, some additions are required. This does not mean that the Android application uses a modified version of the core Elckerlyc platform. The fact that Elckerlyc uses an XML format to define the loading requirements for a specific ECA allows the Android application to simply load its own versions of a few key components. This allows the core Elckerlyc system to be used in the Android application as-is, so any changes to the Elckerlyc core can be directly used in the Android application without having to modify or port it first. The subsystems for which the Android application contains its own versions are discussed here.

A. Graphical Output

Because the Android platform has its own graphical environment, the engines which provide graphical output use a modified component for printing their output in the Android application. This goes for both the PictureEngine, which handles the graphical display of the ECA, and the TextSpeechEngine, which outputs speech elements to a text area. Since PNG images can be handled without problems by the Android graphical environment, the additional code needed to replace the PictureEngine's default output subsystem with a version that works on Android is minimal.

B. SpeechEngine

In the case of the SpeechEngine (for the rendering of spoken text using text-to-speech (TTS)) the differences with Android are unfortunately more severe. The TTS engines used in the PC version of the SpeechEngine contain several dependencies on native PC systems and cannot be used on Android without significant changes. However, Android does offer an internal TTS system. Using this internal system avoids the costly process of porting a TTS engine and any possible efficiency issues this may bring. In order to make use of the internal Android TTS system, an Android adaptation of the Elckerlyc SpeechEngine is needed. This includes the module that loads and initializes the engine, as well as the parts of the system dealing with the actual TTS operations.

The main problem with the Android TTS system is that it is not possible to obtain timing information for utterances, meaning there is no way to find out exactly at what time a word is spoken. This causes the BML scheduler to be unable to use synchronization points within utterances. This makes it hard to precisely synchronize other behaviours with specific words being spoken. A partial solution is that utterances are presynthesized to a file in order to find the total duration of the utterance. This provides the crucial information for the Elckerlyc scheduler. This ”preloading” of utterances causes a delay at startup before the ECA starts playback of the requested BML code.

Furthermore, the TTS also does not offer any viseme information, making it impossible to use real lipsync on Android. This is the main reason the PictureEngine does not currently support true lipsync.

C. Subtitles

Because the PictureEngine can run on a mobile device, the chances of the user having trouble hearing the text spoken by the TTS on the Android system are quite high. This could be caused by factors such as environment noise, low volume or bad speakers. In order for the user to still be able to interact with the ECA in these situations, the Android application also offers an on-screen representation of any spoken text, comparable to subtitling. The TextSpeechEngine (on-screen text display) receives the text handled by the SpeechEngine and displays this in a text area, synchronized (per utterance) with the TTS.

V. APPLICATION

With the growing availability of online services and ubiquitous computing capabilities it becomes easier to develop systems that can support people in changing their behaviour or lifestyle [11]. Sensor data and context information is available anywhere. Many of these systems support people in their daily life by providing support by means of a human or digital coach. These systems can support users in coping with chronic diseases like COPD [12] and diabetes, but also to be more physically active [13] [14]. Persuasive systems [15], and especially behaviour change support systems, are information systems designed to form, alter or reinforce attitudes, behaviours or an act of complying without using deception, coercion or inducements [16].

In the EU Artemis project Smarcos we developed a personal digital health coach that supports users in attaining a healthy lifestyle by giving timely, context-aware feedback about daily activities through a range of interconnected devices. The two targeted user groups of the coaching system are office workers and diabetes type II patients. Office workers will receive feedback about their physical activity level, while diabetes type II patients also receive feedback about their medication intake. Physical activity is measured by a 3D accelerometer and medication intake is tracked by

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a smart pill dispenser. The pill dispenser uses the mobile network to connect to the internet. The system is context-aware and multi-device which means that the (digital) coach can support the users in various contexts and on different devices. GPS information is provided by the mobile phone of the user. The system sends feedback to the mobile phone of the user (iOS or Android), their laptop or PC, and their television.

All input and output devices are connected to the Smarcos cloud. User profiles and preferences, contextual information and sensor data is uploaded to the cloud and stored in a central database. The digital coach continuously keeps track of all user data and contains coaching rules. When the coach receives a trigger it starts to evaluate the coaching rules. When one of the rules is true, it will select a suitable message from the coaching content database and send the message to the user through one of the available output devices and through one of the available modalities. Feedback can be presented using different output modalities Feedback can be sent as a text message, can be presented in a graph or can be presented by animated spoken interaction with an ECA.

Personalisation of the user interface by means of ECA may affect the effectiveness of the behaviour change program and the user experience. Results from other studies indicate that the use of an ECA in a persuasive system has a positive effect on how the feedback is received by the user and on the results of the coaching program [17], [18], [19].

A first user evaluation with a basic version of the Smarcos personal digital health coach compared two alternatives for providing digital coaching to users of a physical activity promotion service. Participants in the study (n=15) received personalised feedback on their physical activity levels for a period of six weeks. Feedback was provided weekly either by e-mail or through an embodied conversational agent. The messages by the ECA were prerecorded video messges. Users' perceptions of the digital coaching was assessed by means of validated questionnaires after three weeks and at the end of the study. Results show significantly higher attractiveness, intelligence and perceived quality of coaching for the ECA coach.

VI. Conclusion and Future Work

To take full advantage of the known benefits of personification of the user interface of service systems, a mobile platform that is able to present embodied conversation agents in mobile applications is presented. The platform makes use of the Elckerlyc system. Because it is too heavy to render realistic 3D virtual humans on mobile devices a light-weight PictureEngine was developed. The PictureEngine makes it possible to use the Elckerlyc system on the Android platform and generate realtime animations of embodied conversational agents. The PictureEngine is used in the Smarcos coaching application as a mobile embodied coach.

Long term user evaluations with the Smarcos coaching platform, including the mobile emdodied coach, are planned to investigate the effects of personified coaching feedback on user experience, quality of coaching and effectiveness of the coaching program.

During a six weeks user experiment 80 participants will use the Smarcos coaching platform for physical activity. Every participant has to meet the daily personal activity goal. The participants will get feedback about their progress on their mobile phone. The system will send feedback to the users with reminders to be more physically active or to upload the activity data, motivational message, tips and a weekly overview of their coaching program.

The design of the user evaluation will be a between subject design. The participants will be divided into two groups of 40 participants each. One group will receive the feedback presented in text, while the other group will receive the feedback presented by the ECA.

The effects on the coaching program of the way of presenting the feedback will be measured by means of questionnaires and by observation of the performance of the participants. During the experiments the progress towards the goal of the user, the actual amount of physical activity and the times the participant uploads their activity data is logged by the system.

At the start, at the end and halfway the experiment the participants will be asked to complete a questionnaire to measure the user experience, the credibility towards the system and the quality of coaching. User experience will be measured by the AttrakDiff2 questionnaire [20], credibility will be measured by the Source Credibility Questionnaire [21] and the quality of coaching will be measures by the Quality of Coaching questionnaire [22].

Although it is shown that the PictureEngine can run on mobile Android devices it would be worth exploring options for using a different TTS system in the future. This would allow the application to regain the speech-related functionality that is currently unavailable on Android, such as synchronization within utterances and viseme-based lipsync. A next step in the development of the PictureEngine is looking for techniques to allow small movements by the ECA, such as nodding and shaking of the head.

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