Virtual Humans in Serious Games

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Abstract

Computers and video games are more and more used for serious purposes such as education and health care. Virtual humans are the inhabitants of the simulated worlds in these games and the challenge is not only to make them look like humans but also to make them behave as humans. Thus, they should be equipped with properties such as social and cognitive intelligence, personality, emotions and user awareness in order to engage the users to the game and to be sensitive to the users' state. This paper gives an overview of serious games applications and mention about research on socially intelligent virtual characters and their use in serious games.

Keywords- intelligent virtual humans, emotion and memory modeling, serious games, expressive character animation

1. Introduction

Most people think that "games" are related with entertainment however they are also used for serious purposes such as education, health care and business. Although applications in terms of military simulations and edutainment had appeared some time ago, the term "Serious Games" started to be used recently with the "Serious Games Initiative" in 2002. Today, serious games are becoming more and more a widely used and several research challenges remains to be solved.

In such games, users are either represented with their avatars and interact with the world and its inhabitants or observe and react to a scenario in order to experience a situation and learn from this virtual experience. Virtual humans are the inhabitants of these worlds and the challenge is not only to make them look like humans but also to make them behave as humans. Thus, they should be equipped with properties such as social and cognitive intelligence, personality, emotions and user awareness in order to engage the users to the game and to be sensitive to the users' state.

In this paper, we mention about the research on socially intelligent virtual characters and explain how they are used in serious games. In section 2, we first mention about different types of serious games and give some examples of them. In section 3, we mention about the research on personality and emotion simulation, episodic memory and expressive behavior generation. In the last section, we describe our own research on creating emotional, intelligent characters and mention about a case study that describes an interaction scenario with a virtual teacher.

2. What are Serious Games?

Today, millions of people in the world, with special focus on the young population, spend their time in front of computers, playing video-games. Such games are often regarded as negative because of their content since they are mostly violent games creating aggressive behavior or they cause people to spend hours sitting in front of the computer without activity. "Serious games" comes to the stage at this point. It is a general term used for applications that are developed using computer game technology and game design principles but rather used for "non-entertainment" purposes. The idea is, games could be used for more important purposes such as educating people, increasing their life quality through health applications or raising interest to the problems in our global world. In the following sections, we enumerate some interesting examples where serious games can be used to ease and to support the people's life.

2.1. Games for Education and Training

Motivation is a key term in education and training. Computer-based education and training applications

are being developed for decades to teach concepts from math, computer science, medical etc. which are called Intelligent Tutoring Systems (ITS). An ITS is mainly composed of three models: an expert model, a student model and a tutoring model and they are also combined with graphical user interface techniques in order to let the users to interact with the system and to observe a simulation of the domain task. Later, these systems were also incorporated with embodied animated tutors called Interactive Animated Pedagogical Agents (IAPD) such as Steve [1] and AutoTutor [2] in order to increase the engagement by the way of adding social interaction capabilities. Such agents are equipped with a conversational and behavior system and may have personality and emotions. They can also motivate the students by encouraging them and by asking questions, or referring to past examples. In some cases, they also perform the domain task themselves and show how to do it. Serious Games use technology from intelligent tutoring, pedagogical agents and virtual worlds and combine those with game techniques since games attract people with challenge and curiosity factors. Traditional tutoring systems are rather the transfer of the textbook to a digital environment which is supported by visual and simulated material in the domain. However, serious games bring the concept of "learning by doing and experimenting". Purdy [3] mentions that games work because they have the potential to assist deep learning. Players make decisions that have consequences and they actively participate in the game environment. They can also safely try out multiple solutions. All are done in a life-like environment with the virtual world technology so that the players can get the similar responses as in the real world. Levels and rewards in the game motivate the player to achieve goals and goals allow players to make progress towards learning objectives.

Tactical Language Training System (TLTS) is an example of serious games on education to teach foreign language and cultural knowledge [4]. Trainees learn by listening to and speaking in the foreign language by interacting with animated "socially intelligent virtual humans" that recognize trainees' speech, gestures and behavior. If trainees speak and behave correctly, the virtual humans become trustful and cooperative, and provide information that trainees need to advance. Otherwise, the virtual humans are uncooperative and prevent trainees from "winning" the game. Today, serious game companies collaborate with educators in order to create tools for schools. For example, 360Ed's Conspiracy Code is a game designed to teach full course in American History developed based on collaboration with K-12 educators [5].

Figure 1. Tactical Language Training System [4]

In addition to the use of serious games in teaching foreign language and in education of young people at schools, they are also used as training tools for professionals. STAR (Services and Training through Augmented Reality) [6] European project is one of the early examples of research for the purpose of training operability of industrial equipments using augmented reality in order to enhance the animations concerning virtual actor's object manipulations. It provides factories digital tools to facilitate the planning and carrying out of routine maintenance inspections and revamp procedures. Hazmat: Hotzone [7] is such training game from Entertainment Technology Center at Carnegie Mellon University to train firefighters for hazardous situations such as a biological attack in a subway situation and developed in collaboration with NewYork Fire Department.

Figure 2. STAR European project [6]

2.2. Games for Health

Serious games are developed both for medical people (doctors, nurses etc.) in the form of medical training and education applications and also for patients, as additional tools for psychological therapy and cognitive or physical rehabilitation.

JUST (JUST-in-time health emergency interventions - Training of non-professionals by Virtual Reality and advanced IT tools) [8] is a European project that addresses the domain of training of non-professional health emergency operators. It aims, through the use of advanced informatics technologies, certified content,

and innovative VR based tools, to provide advanced support for continuous education and training.

Figure 3. JUST European project [8]

Recently, game companies such as TruSim [9], Virtual Heroes [10] and 360Ed [5] produced serious games in order to improve the decision making capabilities of medical personnel in emergency situations (e.g. explosion in a street) using accurate medical simulations of injuries.

Serious games are also used as tools to help Cognitive Behavioral Therapy (CBT) [11]. Many people suffer from behavior disorders (e.g. eating, gambling), phobias (e.g. social phobia, agoraphobia) and post-traumatic stress disorders (PTSDs) that occur after a traumatic event (e.g. wars, accidents with serious physical injury). Exposure therapy is a main technique used by therapists to heal such situations which involves re-experiencing a traumatic experience in a controlled environment. Patients learn to control their anxiety with repeated exposure under the support of the therapist. Virtual reality technology is being used recently in order to simulate these anxiety triggering situations since it is much more cost-effective and also makes the patients feel more comfortable as they know they are not in a real situation. For example, Imprint Interactive [12] and Virtually Better [13] develop serious games for the healing of post-traumatic stress disorders for the survivors of terrorist attacks and war veterans (e.g. Virtual Iraq).

Figure 4. Imprint Interactive's PTSD tool [12]

People suffering from autism are also supported with serious games. Researchers at The Center for BrainHealth at University of Texas have recently conducted a research to enhance the social skills of patients with Asperger's syndrome and other brain disorders [14]. Asperger's syndrome is one of the autism spectrum disorders and people with this disease suffer from significant difficulties in social interaction

in everyday life, even though they have normal intelligence. Using Second Life technology, patients create their own avatar and interact with other avatars in order to learn social situations like "starting a conversation when you want to talk with people".

2.3. Other areas

Serious games are also used in many other areas such as social change and business. The term "Games for Change" is used for video games which address problems related with social issues such as human rights, poverty, global conflict and climate change. For example, Global Conflicts from Serious Games Interactive [15] is inspired by the real events in the world, such as the problems in Mexico or Middle-East. They educate people with simulations of these conflicts and aims to create awareness. Food Force [16] educates people about the hunger problem in famine-affected countries. Serious Games are also used for education in the business area, as a tool for advertising a product or as a recruitment tool for creating interest in a political organization. PIXELearning [17] develops games for staff training in a simulated business environment. In this game, trainees take the role of a product manager, manage product type, pricing and marketing while interacting with simulated characters.

3. Socially Intelligent Virtual Humans

3.1. Personality and Emotion Simulation

Emotions are one of the important mechanisms to control the behavior of virtual characters both for the reason of giving them a personality as well as automatically producing animations by simulating the internal dynamics of the virtual characters.

Gratch and Marsella [18] define two methods for emotion modeling in life-like characters: communicative-driven methods and simulation-based methods. Communicative-driven methods treat emotional displays as a means of communication. These systems does not have an internal calculation of emotion but selects a display of emotion based on the current state of interaction and usually encoded via some scripting language. Simulation-based approaches attempt to model the impact of events on internal emotion dynamics focusing on the cognitive function of emotion. Emotional displays are tied to the virtual character's emotional state rather than being triggered by their communicative function. The first group of systems usually uses categorical models of emotions

such as the six basic emotions introduced by Ekman [19]. Second group of systems model the appraisal of events in the environment and their effects on the internal emotional state. In OCC appraisal model, agent's concerns in an environment are divided into goals (desired states of the world), standards (ideas about how people should act) and preferences (likes and dislikes) [20].

Moods are average internal affective states of an individual. In [18], mood and emotions are differentiated based on three criteria: temporal, expression and cause. Moods last longer than emotions and they are not associated with a specific event. In other words, emotions modulate actions while moods modulate cognition. The relation between mood and emotions is two-way. Mood affects the appraisal of events and decides which emotion will be triggered and with what intensity. For example, if the person is in an anxious mood, it will get more easily disappointed by bad events and with higher intensity. Emotions can also cause a particular mood to occur. For example, a person in a bored mood can become in a more positive mood after some emotional appraisal from the environment. Moods are usually represented with continuous dimensions rather than being discrete labels. For example, activation evaluation [21] and Mehrabian's model of PAD [22] is used for the modeling of moods.

Personality influences the way people perceives their environment and affects their behaviors and actions and distinguish people from one another. Gratch and Marsella [18] define two differences between emotions and personality: duration and focus. Personality is constant and like mood it is not specific to particular events. For example, a person who is stable will have the tendency to behave in a less emotional way in difficult situations. Although there is no universally accepted theory of personality, Five Factor Model or OCEAN model [23] is most widely used in the personality simulation of computer characters.

Another very important factor that shapes our every day emotional reactions is the status of our interpersonal relations with other people. This concept becomes important when the conversational partners are coming together multiple times forming a long-term interaction. In [24], Bickmore mention about five social relationship models based on social psychology:

- *Dyadic models* define relationship as the interdependency between two people such that a change in the state of one will produce a change in the state of the other.

- *Provision models* are based on what one person provides for the other.
- *Economic models*, such as social-exchange theory, model relationships in terms of costs and benefits.
- *Stage models* assume that relationships go through a fixed set of stages.
- *Dimensional models* attempt to abstract a given relationship's characteristics to a point in a small dimensional Euclidean space.

Dimensional models are more widely used for the simulation of computer characters. For example, Argyle [25] proposes a model based on two dimensions: friendliness and dominance.

Personality, mood and emotions are used in many applications as a three layer model. Kshirsagar et. al. [26] uses OCC model for emotions and OCEAN model for personality. Mood is represented as good, bad or neutral and Bayesian Belief Networks are used in order to model the uncertainty in mood change based on different personality. In [27], a generic model is described for emotional communication, where different theory of emotion, mood and personality can be applied. ALMA (A Layered Model of Affect) [28] uses a mood model with three dimensions based on PAD model of Mehrabian. Becker et. al. [29] represents emotion and mood as an orthogonal system where the mutual interaction between them is explained with a mass-spring system. Gockley [30] describes an affective system for a socially-interactive robot based on emotion, mood and attitudes towards users.

3.2. Episodic Memory Modeling

In order to believe that an embodied character is intelligent, it should remember past knowledge and refer to that knowledge where necessary. The character should have a memory that can store and retrieve past experiences, so that it can reason about them and behave appropriately. Besides the reasoning factor, the existence of a real user in the interaction loop makes the use of memory necessary in order to increase the believability of the character from the perspective of the user. The moment the character does not remember a past exchange with the interactant, he/she will feel no more engaged in the interaction, losing his/her trust towards the character. Episodic memory represents our experiences as points on a time-line. In [31], episodic memory is defined as a neuro-cognitive (brain/mind) system, uniquely different from other memory systems that enable human beings to remember past experiences. Semantic memory is derived from

episodic memory and it is a structured representation of learned facts and concepts. For example, remembering what you have done last summer is an episodic memory and your knowledge about a city is semantic memory. Episodic memory stores events in a temporally manner and it is based on the experiencer's view. One of the early example of an episodic memory based agent is the pedagogical training agent Steve [1]. Steve uses an episodic memory structure in order to rationalize his own actions during an after-action review and answers questions of students to rationalize any of his actions during the demonstration. In [32], it has been shown that such kind of autobiographic memory can be integrated with IVAs (Intelligent Virtual Agents) with story-telling capabilities where agents can remember significant past experiences and reconstruct their life stories from these experiences, in an emotion-driven planning architecture. Their model has been used in an application which helps to tackle bullying problems in schools. In this application, a child sees one episode where a bullying situation occurs. After each episode the child interacts with the virtual victim and discusses the problems that arise and propose coping strategies. Brom[33] proposes a virtual role-playing games (RPG) actor with a full episodic memory. In RPGs, it is important that non-player characters (NPCs) can tell believable stories about themselves during interaction with the player characters (PCs). The story should not be predefined but should be constructed dynamically based on what NPCs are experiencing. Therefore there is a need for a full episodic memory and a linguistic module transferring the outcome of the memory to natural language.

3.5. Expressive Behavior Generation

Virtual characters are simulated via an interrelated assembly of several components such as conversational abilities, facial expressions, hand-arm gestures and eye-gaze control. One of the first examples of embodied conversational characters is REA [34] 3D embodied real-estate agent, which is capable of both multimodal input understanding and output generation. GRETA [36] is capable of multimodal interaction with the user through voice, facial expressions, gaze, gesture and body movements. In Egges et al. [37] a virtual character is developed with personalized movements and emotion enabled communication skills with body and through dialogue interaction. Various techniques have been developed so far for the simulation of human-like personality and emotions, facial expressions and gaze which have produced good results. However, they are still far from being intelligent and expressive enough for full engagement

of user to the interaction. The expressions are usually very repetitive and unnatural since they are generated from a limited database of motions. Data-driven methods which use real-human performance data produce realistic results and they are useful tools for automatic generation of the output modalities. For example, for the expressive speech generation, [37] [38] [39] use machine learning techniques in order to learn co-articulation and emotion, whereas [40] is based on the reorganization of motion segments associated with each phoneme based on the animation regeneration technique "motion graphs". Machine learning techniques can also be used for learning expressive head movement from recorded data [41]. For the gaze movement generation, the two trends are data-driven or parametric methods. In Lee et al. [42], a data-driven method is presented based on statistical analysis of eye-tracking data. Fukuyama et al. [43] presents a parametric gaze model based on two-state Markov models where one state is the gazing state and the other one is the averted state which are both better than random models. Another role of facial expressions is in interpersonal communication during dialogue interaction and they are used as signals for communicative acts such as emphasis, confusion and turn-taking [44] For example, BEAT [45] and COMIC [46] are capable of taking text input and converting it to communicative gestures based on the linguistic and contextual information in the text.

4. Case Study: An Emotion and Memory Enabled Virtual Character for Long-Term Interaction

In this section we mention about our research on creating emotion and memory-enabled virtual characters. The aim is to build long-term relationships between the virtual character and multiple users. Our vision is to create everyday "social companions" for people that can interact with them through natural communication, that can perceive and perform emotions and that can have distinct personality to better engage people to the interaction. In order to realize our goals, we focus on three aspects: personality/emotion simulation, self-awareness/memory and expressive behavior generation. The details of the below mentioned research and applied scenario with a virtual teacher can be found in [48].
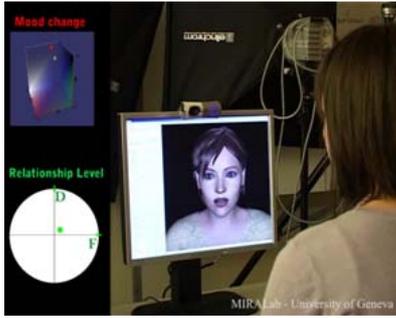
Figure 5. Emotion and Episodic Memory enabled Virtual Character

Personality and Emotion Simulation

In order to realize our goals, we have developed an emotion model based on OCEAN personality [23] and OCC emotional appraisal model [20]. For the implementation of mood, we use the PAD temperament model proposed by Mehrabian [22]. The three traits in the PAD model are pleasure (P), arousal (A), and dominance (D) which are independent from each other forming a three dimensional space. Mehrabian analyzed the relationship between OCEAN personality factors and the PAD scale and presented their conversion as linear regressions. We use this conversion to set up initial moods for the characters based on different personality. Their emotional status and mood is updated with emotional impulses from the environment. After some time, the characters have the tendency to turn back to their initial mood which represents their true personality.

Self-awareness, Memory and Social Relationships

In our model, we also mention about the concept of long-term memory since we want our virtual characters to look more intelligent to people by storing information of past interactions over time and retrieving them back when necessary. For this reason, we developed an episodic memory structure in order to keep track of people that have been interacted and relationships with them. As a relationship model, we use Argyle's model [25] based on two dimensions; friendliness and dominance. The relationship with a user affects the emotional reactions of the virtual character. For example if the user is saying something bad happened to him/her and the character has positive impressions of the person, the resulting emotion will be sorry-for but if the person is not liked, the character will experience the gloating emotion. Relationship update is based on the cumulative evaluation of the individual's overall interaction with the user. For each interaction, positive and negative impulses from user

help to construct a relationship between the interactants. In order to associate events with different users, a face detection and recognition module is integrated into our system.

Expressive Behavior

Expressive behavior is produced by using separate animation generators for lip-synchronized speech, emotional expressions and idle face motions. Lip-synchronized speech is produced automatically by extracting phonemes from written text with the aid of a TTS module. Emotional expressions are controlled by the emotion engine by converting OCC emotion vectors to a basic set of facial expressions from Ekman (happy, sad, angry, fear, disgust and surprise). Face idle motions such as head movement and eye blinking are generated with random movement algorithms in order to create variation during animation. All of the aforementioned facial expression synthesis pieces of information are blended into a single stream in MPEG-4 Facial Animation Parameters (FAP) format and finally facial mesh is deformed based on the FAP stream [48].

Future Research Plans

Our future goal is twofold. First, we would like to improve our episodic memory model so that the virtual character can not only remember overall relationships after each interaction session but also remember specific events in its memory, reason on them and talk about past experiences from his/her own perspective. Second, we would like to improve our behavior generators so that they can be much more natural and un-repetitive.

Construction of episodic memory is very much related with personality and emotion of the character since emotionally salient events are remembered more and have more effect on the character's life. In the episodic memory process it is important to decide on the following questions:

- When an episode will be recorded?
- What information will be stored?
- Which cues can be chosen to store the episode for use in the retrieval process?
- How long an episode will stay in memory, how does it change over time?
- What triggers the retrieval of the episode?
- How does the current situation linked to the episode for retrieval?

After the construction of the episodic memory and personality/emotion simulator, these should be linked with the dialogue manager so that the virtual character can give appropriate responses based on the information received from memory and current emotional state. Besides remembering the past events related with the current dialogue context and giving appropriate responses, we expect the character to tell his/her own experiences by combining multiple entries in the episodic memory so that he/she can answer questions like "What did you today, did you have a nice day?" and start telling you how his/her they has passed, which people he/she has interacted with and which of them he/she liked etc.

For more expressive and natural behavior generation, we plan to use PAD-driven facial expression and head/gaze behavior generators since pleasure-arousal-dominance factors can be well-linked with the quality of the movements such as positive-negative, energetic-unenergetic and dominant-submissive. For example, emotional levels such as arousal and dominance can be linked with gaze movement parameters such as saccade duration, inter-saccade interval or saccade velocity. Head motion is closely related with the prosodic features in speech or in other words it is related with emotions. For example, if the person has a shy personality or is in a disappointed mood, he/she will have the tendency to look down most of the time which is linked with the dominance factor. Or if the person is in a hostile mood while speaking, the head motion will have much more energy and the head will move much faster. We also plan to construct a rich emotional facial expression database which is mapped to the PAD space and develop a mechanism to link current emotional state and mood to the expressions in this database.

Acknowledgement

6. References

[1] J. Rickel and W.L. Johnson. "Animated agents for procedural training in virtual reality: Perception, cognition, and motor control", *Applied Artificial Intelligence*, Taylor & Francis, vol.13, 1999, pp. 343–382

[2] A.C Graesser,. P. Chipman, , B.C. Haynes, & A.. Olney, "AutoTutor: An intelligent tutoring system with mixed-initiative dialogue". *IEEE Transactions in Education*, vol. 48, 2005, pp. 612-618.

[3] J. A. Purdy, "Serious Games: Getting Serious About Digital Games in Learning", *Corporate University XChange*, Issue 1, 2007.

[4] W. Lewis Johnson, Alelo, Inc. and the University of Southern California, "Serious Use of a Serious Game for Language Learning", *Artificial Intelligence in Education (AIED)*, Los Angeles, US, 2007.

[5] http://www.360ed.com

[6] L. Vacchetti, V. Lepetit, M. Ponder, G. Papagiannakis, P. Fua, D. Thalmann, N. Magnenat-Thalmann. "Stable Real-time AR Framework for Training and Planning in Industrial Environments", *Virtual Reality and Augmented Reality Applications in Manufacturing*, *Springer*, 2004, pp. 129-146.

[7] http://www.etc.cmu.edu/projects/hazmat_2005

[8] M. Ponder, B. Herbelin, T. Molet, S. Schertenleib, B. Ulicny, G. Papagiannakis, N. Magnenat-Thalmann, D. Thalmann, "Interactive Scenario Immersion: Health Emergency Decision Training in JUST Project", *Proceedings of The First International Workshop on Virtual Reality Rehabilitation (VRMHR)*, 2002.

[9] http://www.trusim.com

[10] http://www.virtualheroes.com

[11] V. Brezinka, L. Hovestadt, "Serious games can support psychotherapy of children and adolescents", *Third Symposium of the Workgroup Human-Computer Interaction and Usability Engineering of the Austrian Computer Society*, Austria, 2007, pp. 357-364.

[12] http://www.firsthand.com

[13] http://www.virtuallybetter.com

[14] http://www.brainhealth.utdallas.edu

[15] http://www.seriousgames.dk

[16] http://www.food-force.com

[17] http://www.pixelearning.com

[18] J. Gratch and S. Marsella, "Lessons from Emotion Psychology for the Design of Lifelike Characters," *Applied Artificial Intelligence*, vol. 19, no. 3–4, 2005, pp. 215–233.

[19] P. Ekman, *Emotion in the Human Face*, Cambridge University Press, 1982.

[20] A. Ortony, "On Making Believable Emotional Agents Believable," *Emotions in Humans and Artifacts*, R. Trappl et al., eds., MIT Press, 2003, pp. 189–212.

[21] C.M. Whissel, in: *The Dictionary of Affect in Language*, R. Plutchik and H. Kellerman, eds, Emotion: Theory, research, and experience, 4, The measurement of emotions, 1980.

[22] A. Mehrabian, "Analysis of the Big-Five Personality Factors in Terms of the PAD Temperament Model," *Australian Journal of Psychology*, vol. 48, no. 2, 1996, pp. 86–92.

[23] S. Hampson, "State of the Art: Personality," *The Psychologist*, vol. 12, no. 6, 1999, pp. 284–290.

[24] T.W. Bickmore and R.W. Picard, "Establishing and Maintaining Long-Term Human–Computer Relationships," *ACM Trans. Computer–Human Interaction*, vol. 12, no. 2, 2005, pp. 293–327.

[25] M. Argyle, *Bodily Communication,* 2nd ed., Methuen, 1998.

[26] S. Kshirsagar and N. Magnenat-Thalmann. "A multilayer personality model", in *ACM International Conference Proceeding Series*, vol. 24, 2002, pp. 107-115,

[27] Egges A. Kshirsagar S. and Magnenat-Thalmann N. "Generic personality and emotion simulation for conversational agents", *Computer Animation and Virtual Worlds*, vol.15, no. 1, 2004, pp. 1-13.

[28] P. Gebhard. "Alma - A layered model of affect". In *Proceedings of the Fourth International Joint Conference on Autonomous Agents and Multi Agent Systems*, 2005, pp. 29-36.

[29] C. Becker, S. Kopp, and I. Wachsmuth, "Simulating the emotion dynamics of a multimodal conversational agent", in *Proceedings of Affective Dialogue Systems: Tutorial and research workshop (ADS 2004)*, *LNCS 3068*, 2004, pp. 154-165.

[30] R Gockley, R. Simmons and J. Forlizzi, "Modeling affect in socially interactive robots", in *The 15th IEEE International Symposium on Robot and Human Interactive Communication (RO-MAN06)*, 2006.

[31] E. Tulving. *Elements of Episodic Memory*, Claredon Press, Oxford, 1983.

[32] W. C. Ho and K. Dautenhahn, "Towards a narrative mind: Creating coherent life stories for believable agents", in *Proceedings of Intelligent Virtual Agent (IVA)*, 2008, pp. 59-72.

[33] J. Lukavsk, C. Brom and K. Peskov, "What does your actor remember? Towards characters with a full episodic memory", in *International Conference on Virtual Storytelling*, 2007, pp. 89-101.

[34] J. Cassell., T. Bickmore, M. Billinghurst., L. Campbell, K. Chang., H. Vilhjalmsson and H.Yan., "Embodiment in Conversational Interfaces: Rea", *Proceedings of the CHI'99 Conference*, 1999.

[35] C. Pelachaud, B. Hartmann and M. Mancini, "Implementing Expressive Gesture Synthesis for Embodied Conversational Agents", in *Gesture Workshop*, LNAI, Springer, 2005, pp. 188–199.

[36] A. Egges, T. Molet., N. Magnenat-Thalmann, "Personalised Realtime Idle Motion Synthesis", *Pacific Graphics*, Seoul, Korea, 2004, pp. 121-130.

[37] S. Kshirsagar, N. Magnenat-Thalmann, "Visyllable Based Speech Animation. Computer Graphics Forum", Proc. of Eurographics, Blackwell Publishing, vol. 22, no. 3, 2003, pp. 632-640.

[38] Z. Deng. and U. Neumann, "eFASE: Expressive Facial Animation Synthesis and Editing with Phoneme-Isomap Controls", *Proc. of ACM SIGGRAPH /EG Symposium on Computer Animation (SCA 2006)*, Vienna, Austria, 2006, pp. 251-259.

[39] I.-J Kim and H.-S. Ko, "3D Lip-Synch Generation with Data-Faithful Machine Learning", Proc. of Eurographics, Computer Graphics Forum, vol 26, no 3, 2007.

[40] Y. Cao, P. Faloutsos, F. Pighin., "Expressive Speech Driven Facial Animation", ACM Transactions on Graphics, vol. 24 , no. 4, 2005, pp. 1283 – 1302.

[41] C. Busso, Z. Deng, U. Neumann and S. Narayanan, "Learning expressive human-like head motion sequences from speech", in *Z. Deng and U. Neumann, editors, Data-Driven 3D Facial Animations*, Springer-Verlag Press, 2007, pp. 113–131.

[42] S. P. Lee, J. B. Badler, and N. I Badler, "Eyes alive", in Proc. of ACM SIGGRAPH, ACM Press, 2003, pp. 637–644.

[43] A. Fukayama, T. Ohno, N. Mukawa, Sawaki M., N. Hagitan, "Messages embedded in gaze of interface agents-impression management with agent's gaze", in Proc. of SIGCHI, 2002, pp. 41–48.

[44] J. Cassell, , C. Pelachaud, N. Badler, M. Steedman, B. Achorn, W. Becket, B. Douville, S. Prevost and M . Stone, "Animated conversation: Rule-based generation of facial expression, gesture and spoken intonation for multiple conversational agents", in *Proc. of ACM SIGGRAPH*, 1994.

[45] J. Cassell, H. Vilhjalmsson, T. W. Bickmore, "Beat: The behaviour expression animation toolkit", in *Proc. of the 28th annual conference on Computer graphics and interactive techniques (SIGGRAPH),* 2001, pp. 477–486.

[46] M.E. Foster, and J. Oberlander, "Corpus-based generation of head and eyebrow motion for an embodied conversational agent", *International Journal of Language Resources and Evaluation*, vol 41, 2007, pp. 305-323.

[47] Z. Kasap, M. Ben Moussa, P. Chaudhuri, N. Magnenat-Thalmann, "Making Them Remember—Emotional Virtual Characters with Memory," *IEEE Computer Graphics and Applications*, vol. 29, no. 2, 2009, pp. 20-29.

[48] S. Kshirsagar, S. Garchery, N. Magnenat-Thalmann, "Feature Point Based Mesh deformation Applied to MPEG-4 Facial Animation. Deformable Avatars", Kluwer Academic Publishers, 2001, pp. 23-34.