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Intelligent virtual humans with autonomy and personality: State-of-the-art

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Abstract. Intelligent virtual characters has been subject to exponential growth in the last decades and they are utilized in many application areas such as education, training, human-computer interfaces and entertainment. In this paper, we present a state-of-the-art of virtual human mentioning about the use of intelligent decision technologies in order to build virtual human architectures. We consider various aspects such as autonomy, interaction and personification. Each of these aspects comes to prominence in different applications. This survey provides a novel insight to the current state of designing and modeling virtual humans using different decision technologies and can be used as a basis for several future directions.

Keywords: Intelligent virtual human, decision-making, interaction

1. Introduction

The metaphor of intelligent and human-like computer characters has been around for a long time and they are the result of the convergence of several fields such as computer graphics, computer animation, artificial intelligence, human-computer interaction and cognitive science. It also has close relationships to the robotics area since they can share the same know-how in order to model the cognitive behaviour of autonomous individuals. The impetus of the area also comes from the variety of application areas from training/education systems to human-computer interfaces and entertainment films/computer games. Each of these application areas requires different properties at different levels such as autonomous behaviour, natural language communication, recognition of real people, personality modeling, emotional behaviour, adaptation to environmental constraints, user needs, intentions and emotions. In order to build such virtual human architectures, several intelligent decision technologies are utilized such as artificial neural networks and hidden-markov models.

The paper is organized as follows. First, we mention about autonomous behaviour of virtual characters considering both the internal state of the virtual human and the state of the virtual environment. Several concepts such as perception, decision-making, adaptation, action selection and action control are mentioned. Second section represents the importance of interaction capabilities of virtual humans by giving examples of Embodied Conversational Agents (ECAs) and mentioning about different components of interaction such as facial expressions, gestures and dialogue. In the third section, another important factor of virtual characters called personification is considered, first referencing to some psychological models of emotion and personality and later to some examples of computational models considering the effects of emotion and personality on the behaviour and apperance of virtual human. Finally, we conclude with a summary of our discussion in this paper.

2. Autonomous behavior

With the occurence of real-time applications such as computer games and human-computer interfaces, autonomous behavior of virtual characters has become to be important. In [94], Tomlinson mentions that traditionally animation was produced by specifying every frame in the mind of the creator and the characters

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do not have the ability of self-controlling their actions. This kind of technique is applied in many famous films like Shrek and Happy Feet. However, in a real-time application characters should decide what to do at a specific time by themselves based on some pre-defined rules like in the well-known game The Sims.

Before going into the literature of autonomous virtual humans, we first want to give the definition of the terms autonomy and behavior. Autonomy is defined as the self-governing of one's actions and acting independent of someone's control. Two reasons to have autonomous behavior is defined in [103]: fidelity of the virtual life to the real one and less work load for the designer since it is a long and difficult process to design every frame exactly. Behavior refers to the actions or reactions of an object or organism, usually in relation to the environment [107]. Behavioral animation of virtual humans is a complex topic requiring analysis of cognitive and emotional processes. We will mention about three important levels in autonomy of virtual humans in the following sections: perception, decision-making and action control.

2.1. Perception

In real world, people as autonomous agents only perceive a part of the environment where the conditions are unpredictable and changing continuously triggering a behavior in the human being. In [12] it is mentioned that doing the same thing for virtual environments requires having the same limitations as real in order to convince the user. In other words, virtual environments are created by a designer and all information about the virtual environment is available to the agent for example through a scene graph. Human like perception of the environment needs to be simulated to apply these constraints.

Earlier examples that models visual perception of autonomous characters can be found in Reynolds [81] where bird boids were able to perceive the distance to other boids. Synthetic vision is first introduced by Renault [59] where an actor navigates in a corridor avoiding obstacles by off-screen rendering of the scene from the point of view of the agent. This technique later applied by Tu and Terzopoulos [97] in the perception system of artificial fishes. The technique is based on ray-casting which means simply sending and checking the rays are reaching to which objects. Blumberg [93] used synthetic vision for his autonomous virtual dog in order to avoid obstacles. Noser et al. [92] proposed a synthetic vision model based on false-coloring and dynamic octrees. In [80] active perception of virtual soldiers is modeled based on binocular perspective projection of the color 3D world onto the animat's 2D retinas. In [74], synthetic vision model is extended with two different vision modes. In distinct mode false-coloring is applied to each distant object and in some cases objects are grouped according to some different criteria that is called grouped vision mode. A different approach to synthetic vision is proposed in [16] based on perceptual filters which receives a perceptible entity from the scene and decide if to pass or not. A main distinction between virtual human perception models is whether they are based on task perception or biological perception [43]. Biological perception or bottom-up visual attention is an alerting mechanism to unexpected dangers as explained in [75]. Task-based or top-down approaches such as [23,38] consider task-related objects as the focus of attention. Despite it is rare, aural perception is also modeled and applied by some researchers. Lehnert [55] mentions about the fundamentals of auditory virtual environments. A recent example in [41] describes a framework to capture the position of the sound source and mention about some concepts related with human auditory perception such as interaural differences, auditory acuity and auditory filter.

2.2. Decision-making and adaptation

Decision-making is the evaluation of what is perceived through reasoning and choosing the appropriate action to perform which is also named as action-selection process. This evaluation is not only based on the physical properties of what is perceived from the environment but also it depends on various properties of the perceiver such as intelligence, past experiences, current motivations, plans, personality and emotional state. According to this interpretation of the environment, people decide what to do with the current situation and select among different alternative actions that move them to a better state.

Most of the studies separate the modeling of mind and actions from each other since human mind does not think of every detail of body motions such as "Now I need to make a step with my left foot" but rather focus on higher level goals such as "I will go to the supermarket". Improv system of Perlin [73] uses a three layer architecture where the lowest layer geometry of the characters are manipulated in real-time by an animation engine and high-level capabilities are controlled by behavior engine which simulates the mind. In SimHuman [102], there are two different modules such as motion controller and behavior controller which are part of the sense-decide-act sequence. There are various approaches of decision-making (action selection) for intelligent agents [109]. Earliest approaches to action selection are based on symbolic reasoning and solved with logical deduction and theorem proving which is not suitable for real-time systems. A well-known cognitive architecture based on symbolic reasoning is the Soar project [79]. The training expert Steve [82] uses the Soar architecture in its cognition module. Problems in the symbolic approach caused a new approach called reactive approach to appear which is more suitable for dynamic environments. The best-known reactive architecture is the sub-sumption architecture of Brooks [19] where behaviors are represented as simple if-then like structures and take place in a hierarchical structure where each agent has precedence over another [109]. Finite State Machines (FSMs) are also used as reactive architectures where affect of a condition on the current state results in a new state. Probabilistic and fuzzy approaches are also used for reactive agents [46]. Another group of researchers combine deliberative and reactive approaches resulting in a hybrid architecture that consists of both symbolic models and reactive models [32,65]. Goal-driven architectures are most widely used in virtual applications such as Belief-Desire-Intention (BDI) architecture. Belief stands for the agent's knowledge about the world, desires are the objectives to be accomplished and intentions are what the agents have chosen to do [101]. BDI is based on practical reasoning [18] which is the process of deciding what to do in each moment of time in order to achieve the goals. An overview of BDI-style agents in the literature such as PRS, dMars and JACK can be found in [101]. Decision-making in virtual environments is applied in many other different applications. A constraint satisfaction framework for the planning of any-time agents in computer games is proposed and applied in the EXCALIBUR project [66]. A more recent example is [22] where a decision-planning framework is developed for open-ended scenario environments where virtual characters face unexpected situations either from user interaction or reactions in the environment. The framework is based on ontologies representing the environment as interconnected concepts and it becomes easier to infer relations between objects.

Living in a dynamic environment requires the ability of learning what to do in unexpected situations, which is also called adaptation. Perceptions can also be considered as acceptable or unacceptable according to the social rules and virtual one can learn not to show unacceptable behavior. Intelligence and emotions helps us in coping with unpredictable situations. Intelligence is rather related with reasoning, planning, problem-solving and requires abstract thinking ability to give logical decisions. Adaptation can also be achieved through governing emotions to stressful conditions. Agent frameworks without learning are composed of pre-defined perception-action rules, however adaptation requires to construct the behaviour rules in time learning through experiences. Learning approaches are connectionist approaches e.g. artificial neural networks and evolutionary approaches e.g. genetic algorithms. Learning through interaction with human user is rather a new area that is paid attention in the last years. For example a work done at MIT Synthetic Characters Group aims to train a virtual dog through clicker training in interaction with human using reinforcement learning technique [57]. Another example of emotional learning is the ALEC agent architecture [35] which has both emotive and cognitive learning and decision making capabilities using mainly neural networks. In [91] an autonomous virtual character learns to do a specific task such as jumping over obstacles using evolutionary algorithms. Imitation can also be used in learning. In [28] emotional learning and imitation are combined enabling a virtual character to quickly adapt online due to interaction with human user.

2.3. Action control

Movements of virtual humans can be investigated under two groups. One group of movements occurs during conversation such as facial expressions, gestures and posture changes. We will mention about these in more detail in Section 3. Realistic synchronization of these movements leads to more fidelity. There are also other types of actions such as taking a glass of water which requires the study of complex movements of the body such as walking, running and grasping an object. Because of this complexity, realistic synchronization of these actions is important since sometimes it is possible to perform some actions concurrently and it is necessary to control the transitions between actions. For example, a person can be running while carrying something in his/her hand but can not be running and sitting at the same time. PaT-Nets (Parallel Transition Networks) [69] are finite state automata running in parallel in order to provide such synchronization. The nodes of the net are processes and the arcs contains predicates and conditions which provides a non-linear animation model since movements can be triggered, modified and stopped by transitions to other nodes.

In [37] it is mentioned that autonomous behavior should be integrated with user control in some systems. In order to believe that virtual humans are intelligent, we want them to understand our high level commands such as walk, open the door, go to school. In other words, given a goal by the human user, they should be autonomously realizing and reacting to it. Such kind of architecture is proposed by Badler et al. [88] in order to fill the gap between natural language instructions and activities. Parametric Action Representation (PAR) gives a desription of an action with properties such as performer of the action, objects used during the action or path followed, location, manner and purpose of the action [9]. A natural instruction such as "Walk to the door and turn the handle slowly" is represented as a parameterized form to be converted to animations with specified properties [112].

3. Interaction

For being convinced that a virtual character has a particular amount of intelligence, we would like to interact with them just like we do with real human. In order to realize this, an assembly of several components such as conversational abilities, facial expressions, hand-arm gestures and eye-gaze are required. Agents with these capabilities are called Embodied Conversational Agents (ECAs) [78]. Before mentioning about the techniques for the creation of human-like computer characters, we would like to mention about some examples of ECAs available in the literature and and their abilities so that it is possible to understand what is available currently and what can be the future directions.

One of the first examples of ECAs is REA [100], 3D embodied real-estate agent, which is capable of both multimodal input understanding and output generation through gesture recognition, speech recognition, discourse, speech planning and speech synthesis. REA uses a mixed initiative dialogue management pursuing the goal of describing the features of the house that fits the user's requirements while also responding to user's verbal and non-verbal input that may lead to new directions. BEAT (The Behavior Expression Animation Toolkit) [99] is a first example of animation tools that uses natural language understanding techniques to extract the linguistic and contextual information contained in the text to control the movements of different modalities such as hands, arms, face and the intonation of voice. It realizes written text into embodied expressive behaviors just as text-to-speech systems realize written text into spoken language [99]. STEVE (Soar Training Expert for Virtual Environments) [82] is an animated pedagogical agent that teaches students how to perform procedural tasks such as operating and repairing equipment. MAX (Multimodal Assembly Expert) [50] is capable of demonstrating assembly procedures to the user in an immersive virtual environment. MACK (Media Lab Autonomous Conversational Kiosk) [98] is an ECA Kiosk that is able to answer questions about MIT Media Lab and give directions to its various research groups, projects and people. GRETA [13] is an embodied conversational agent that is capable of multimodal interaction with the user through voice, facial expressions, gaze, gesture and body movements. Another ECA developed at MIRALab (Fig. 1) is capable of natural animation in real time with the consideration of idle motions such as posture changes from one resting position to another and continuous small posture variations caused by breathing, maintaining equilibrium [3]. MIRALab-ECA is also capable of emotional communication considering different personality types. In this section, we classify the techniques for the development of ECAs into three categories: facial expressions, gestures and dialogue.

3.1. *Facial expressions*

Computer animation techniques are evolving more and more in order to create more realistic virtual characters. Face is the first point of attention when one looks at an embodied agent and this is the reason that there have been lots of effort to improve facial animation techniques. [21] defines facial animation techniques under three categories. A similar categorization is also done in [47]. First method is based on manually generating key-frames and interpolating between them. This is done by manipulating the facial mesh at a low level in order to create morph targets or keyframes and interpolating between them. This technique is especially used in film industry since it gives very good results as a result of artistic work applied on a particular model. Second method of facial animation is based on automatically extracting visemes – visual counterparts of phonemes – from written text with the help of a text-to-speech tool or from acoustic speech with the help of speech recognizer techniques in order do synthesize speech with lip-synchronization. Third technique of facial animation is based on parameterization of the facial mesh with certain feature points, representing the

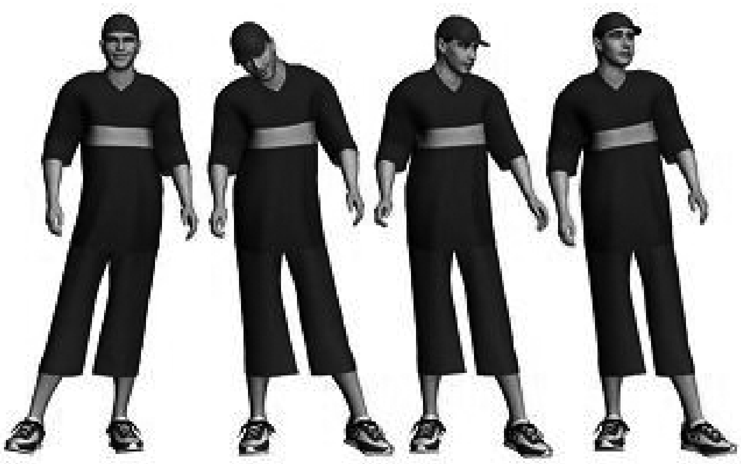

Fig. 1. Embodied Conversational Agent at MIRALab.

captured data according to these feature points in order to analyse and synthesize. Second and third techniques of facial animation will be explained in more detail in the next pharagraphs.

Earlier work on computer generated animation of faces starts in 1972 by Parke [71]. Later, Pearce et al. [6] developed a system that enables the manual entrance of a phonetic script that would result in synchronized lip movements. Automated methods of lip-synchronization started in the second half of 1980s and followed two paths: computer synthesized speech and recorded speech. The former involves automatic generation of speech animation from typed text. Earlier work done in this field can be found in Hill et al. [26]. Various facial animation systems that use different text-to-speech systems are developed later on such as [39, 104]. Steps in creating speech animation are well defined in [47]. Phoneme timing information coming from a text-to-speech (TTS) system is used for mapping phonemes to visemes which are predefined and stored in a viseme database. Building blocks of speech animation coming from a viseme database are interpolated according to the timing information in the phoneme stream coming from the TTS system. In order to obtain realism in speech animation, simple interpolation between phonemes is not enough since each phonetic segment is influenced by its neighboring segments which is called coarticulation. Approaches for computing the effects of coarticulation can be found in [24,72]. Although computer synthesized speech from text is good for providing accurate synchronization between speech and lip movements, it is still lack of properties such as natural rhytm, articulation and intonation provided in natural speech [56].

For more realism it is also possible to extract phoneme information from recorded speech although it has its own disadvantages. Specifing phoneme timings from natural speech is a challenging task and requires the use of different techniques for extracting the parameters in a speech signal such as Linear Predictive Coefficients, Fourier Transform Coefficients, Mel-Cepstral Coefficients as well as pitch and energy [47]. Machine Learning techniques such as Hidden Markov Models (HMMs) and Neural Networks (NNs) are used to train the processed audio and processed visual data or statistical techniques such as Principal Component Analysis (PCA) are used to analyze the parameters in recorded speech e.g. [29,64]. In [17], Voice Puppetry system is presented for the generation of face animation from expressive information in an audio track [110] describes a video realistic speech animation technique using a small video corpus.

Third method of facial animation is based on the parameterization of the facial animation. Previously, facial animation was being done by manipulating the facial mesh at a low level and interpolating between keyframes. However, it has some disadvantages since the development process is slow and needs artistic efforts of designers. Once an animation is created for a particular face it can not be applied to other facial meshes. Techniques that can automatically and easily produce facial animation and that can be applied on any facial model are important for an ideal facial animation system. Parameterized models address this problem and they allow to generate facial expressions by manipulating a set of parameters. Animations are specified in terms of these parameters so that an animation can be applied on another facial mesh that contains the same feature point information. Earliest parameterization technique for facial animation is the Facial Action Coding System (FACS) developed by Ekman and Friesen [34]. Recently, MPEG-4 facial animation standard is accepted and widely used for 3D facial animation. More information about MPEG-4 facial animation standard and its implementations can be found in [10]. Feature point based geometric deformation methods are used for the animation of parameterized facial meshes [85]. Other examples of parameterized facial mesh deformation can be found in [53,86]. There are various methods of facial deformation such as finite element method, muscle based modeling, pseudo muscles, spline models and free-form deformations. For a more detailed survey of facial deformation techniques, we refer to [68].

In order to build realistic faces, eye movement is also important. The effect of eye engagement during social interaction and discourse is mentioned in some studies such as [15,42,44]. According to these studies gaze can be used as a signal of paying attention and takes a regulatory role during conversation.

3.2. Gestures

Gesture is a form of non-verbal communication that causes a particular change in the shape of the arms and body in order to convey complementary information to discourse. Gestures are different from other movements of body such as grasping and reaching in that they carry the semantic characteristics related with the content of the speech [49]. In order to develop computational models of gestures, some form of parameterization is required for the description of qualitative aspects of gestures. McNeill [62] classifies gestures into several categories such as iconics, metaphorics, deictics, beats and emblems. A different approach to parameterization of gestures is applied in the EMOTE (Expressive MOTion Engine) system [111] which usues effort and shape parameters of Laban Movement Analysis (LMA) [52] in order to generate more natural synthetic gestures.

Studies in believable gesture generation can be grouped into two directions. One group is concerned with semantic aspects of gestures such as timing. Automatic prediction of gesture timing from synthesized speech has been studied in some systems such as BEAT [99], REA [100] and MACK [98]. In [62], four different phases of gesture is defined: preparation, stroke, hold and retraction. Stroke is the mandatory part of a gesture that carry the meaning. Usually the solution with timing of gesture is matching the stroke part of the gesture with the most emphasized part of the utterance [48] describes a study that extends the work in BEAT, REA and MACK where the form of gesture is derived on-the-fly without relying on a lexicon of gesture shapes or "gestionary". Another more recent example is GESTYLE [83] that brings the notion of style in forms of gesturing motion characteristics (expansive/subdued), gesturing frequency and gesturing repertoire.

Second group of researchers are more concerned with realistic generation of gesture movements. The quality of the resulting animation in the above mentioned systems is limited since the animations are generated procedurally only for a few joints resulting a mechanic animation. In nature, a gesture is not just composed of the movements of a few joints but influences of each movement of a joint on other joints should also be considered. In [3], an animation synthesizer that allows the generation of small posture variations and posture shifts is described. Another research in [54] describe a method for using a database of recorded speech and captured motion to create an animated conversational character. Motion samples are combined with new speech samples and they are blended phrase-by-phrase into extended utterances.

3.3. Dialogue management

Natural language dialogue is a very important part of the interaction between human and machine. A believable dialogue system requires the integration of the functionalities such as response generation according to emotional state, allowing interruptions, repairing of dialogue, feedback and turn-taking.

Some features of discourse and difficulties of modeling dialogue are mentioned in the survey [11]. A dialogue has an opening, body and closing and although the user takes control in most parts of the dialogue, the overall dialogue should be the result of a mixed initiative between user and agent. In dialogue it is common that we use incomplete sentences in order to explain something in short or as a result of our speaking style. This incomplete information should be recovered from the context of the dialogue. A recovery mechanism is also required when one side of the conversation can not understand the other one and it is the case with computers since they are not able to understand every word we say. Another feature of dialogue is about indirectness where cognitive skills are required to understand the overall meaning of dialogue. Turn-taking requires deciding when one of the speakers start talking or give turn to the other speaker and it becomes more complicated when there are more than two speakers. The use of fillers such as the words 'a-ha' and 'yes' are important in order to give feedback to the other speaker to show that you are paying attention to what he/she is saying. Non-spoken period of speech should also be interpreted as a part of the dialogue for more realistic conversation.

In [96] four approaches to dialogue systems are defined: (1) finite-state based and frame-based systems (2) information state and probabilistic approaches (3) plan-based approaches and (4) collaborative agent-based approaches. In finite-state based approaches, dialogue is composed of a sequence of predetermined states and flow of dialogue is determined by transitions between states. Frame-based approach is an extension of finite-state based approach addressing the problem of flexibility. The user is asked questions in order to fill in the slots for a given template related with a task such as a train timetable [63]. Information state approach is an effort to overcome the limitations of finite-state based and frame-based approaches. It is composed of informational components such as participants, linguistic and intentional structures, beliefs and their formal representations such as lists, sets, records and so on. An information state is updated through dialogue moves based on update rules and update strategy. Plan-based approach is more complex than the previous approaches and originates from the idea that humans communicate to achieve a particular goal. Collaborative approaches or agent-based dialogue management approaches are based on viewing dialogues as a collaborative process between intelligent agents. Both agents work together to achieve a mutual understanding of the dialogue.

ELIZA [105] is one of the first attempts for dialogue generation which is based on pattern-matching techniques that allows generating standard answers to certain word combinations in a given phrase. Another well known program, ALICE [8] which is an extension of ELIZA utilizes an XML based language AIML – Artificial Intelligence Modeling Language. In [30] a dialogue model similar to ALICE is presented but with some extensions to consider different emotional states. A parallel Finite State Machine (FSM) algorithm is applied where several FSMs run concurrently and each FSM represents a dialogue unit about a certain topic.

One of the more recent examples of dialogue systems is TRINDIKIT framework [95] which focuses on the development of new technologies for adaptive multimodal and multilingual human-computer dialogue systems. TRINDIKIT is a toolkit for building and experimenting with dialogue move engines and information states and is an example of information state approach mentioned above. For a more detailed information about dialogue systems, we refer to [63,96].

4. Personification

Personification means giving human properties to non-human objects and this issue is becoming to be important in the world of virtual humans in the last years. While looking at the perspective of traditional intelligent systems such as expert systems or decision support system, having emotions can be seen as a non-desirable property. However, this is not the case for the domain of believable agents since we prefer them to behave as human as possible. Social behavior of computer characters with emotion and personality increases the realism and quality of interaction such as in games, story-telling systems, interactive dramas, training systems and therapy systems. They also can replace many of the service areas that real people are employed such as a museum guide or a receptionist. In [33], a social robot that is placing a receptionist in a hotel is presented. The robot has a LCD head that displays a highly expressive graphical face and is capable of conveying different moods such as neutral, positive and negative. It is observed that people prefer to interact with negative receptionist for shorter periods. In the Mission Rehearsal Project [60], lieutenants learn to cope with dramatic situations such as in a war and improve their decision-making capabilities under stressful conditions.

When we talk about personification, we usually consider two factors: Personality and Emotion. Personality is a phenomenon that makes it available to distinguish between different people. This is also the case in our interaction with virtual characters. When we are immersed into a virtual environment populated with virtual humans, experiencing that they all behave differently under same conditions increases their believability. Emotion is another major component of personification since in real life emotions affect people's all cognitive processes, their perceptions, beliefs and the way they behave. The importance of emotions as a crucial part of virtual humans is previously mentioned in [76].

Empathy is another property of personified virtual characters and a key factor to increase believability. On one side a virtual character can behave in a way that leads the user to establish emphatic relation with it or the agent itself can be emphatic and behave in an emphatic way towards other agents and towards the user [5]. FearNot! [5] is a project addressing the bullying problems in schools letting the children users to establish emphatic relations with the characters in the virtual environment. There are many other issues in the personification of virtual characters. In [89] they ask the question if it is possible to develop friend-ECAs so that interaction with that character or learning from it becomes more fun. Humour is another important property of real people and can be very useful in human-computer interaction increasing the level of joy and this leads to more cooperation between user and agent [67].

Several models of emotion and personality are developed in the domain of psychology. However, these models are usually produced for the purpose of psychological studies rather than being used in the creation of computational characters. This gap between the models of emotion and personality and the complexity of modeling human feelings will keep this area as the focus of attention for many computer scientists for the future. In the next sections, we will first examine different models of personality and emotion in the literature. Second we will mention about some examples of virtual characters that are developed based on these models. The effects of emotions on different parts of a character's body (e.g. face, body and gaze) will be considered in addition to their effects on the character's actions and decisions.

4.1. Personality

Personality influences the way people perceives their environment, effects their behaviors and distinguish one from another. Although there is no universally accepted theory of personality, Five Factor Model or OCEAN model [61] are most widely used one in the simulation of computer characters. According to this model, personality of a person can be defined according to five different traits: openness, conscientiousness, extroversion, agreeableness and neuroticism and they are explained in [40]. Openness means being open to experience new things, being imaginative, intelligent and creative whereas conscientiousness indicates responsibility, reliability and tidiness. In other words, conscientious people think about all the outputs of their behaviors before taking action and take the responsibility. An extravert person is outgoing, sociable, assertive and energetic to achieve his/her goals. Agreeableness means a person is trustable, kind and cooperative considering other people's goals and is ready to surrender his own goals. At last, a neurotic person is anxious, nervous, prone to depression and lack of emotional stability. Usually, a character is represented as a combination of these traits possibly with emphasize on one of them. Although this static trait-based model of personality does not reflect the complexity of human behavior truly, it has been widely accepted to be used in computational models because of its simplicity.

4.2. Emotion

There is a variety of psychological researches on emotion and they are classified into four different theoretical perspectives: Darwinian, Jamesian, cognitive and social constructivist approaches [25]. In order to create computational models of emotions we need some annotation mechanisms. Ekman [31] defines six basic labels for emotions: fear, disgust, anger, sadness, surprise and joy following the Darwinian approach to emotions emphasizing the universality of human emotions. Recently, cognitive appraisal models of emotion are becoming to be more preferred since they better explain the overall process of how emotions occur and affect our decision-making. Appraisal means a person's assessment of the environment including not only current conditions but past events as well as future prospects [45]. OCC model of Ortony, Clore and Collins [4] is widely used for emotion simulation of embodied agents. In OCC model, agent's concerns in an environment are divided into goals, standards, and preferences and twenty-two emotion labels are defined.

In addition to the four theoretical approaches mentioned above, there are also some studies on emotions based on neurophysiology. The first representative of this approach is Plutchik [77] who defines eight emotions in an emotion spectrum like the color spectrum and it is possible to produce new emotion labels by the way of mixing these emotions (e.g. disappointment = sadness + surprise). Other models of emotion such as activation-evaluation [106] defines emotions according to abstract and continuous dimensions rather than discrete labels.

4.3. Applications to virtual human

Various applications are developed that uses the above mentioned psychological models of emotions and personality. [14] describes what the OCC model of emotions is able to do for an embodied emotional character and what it does not. The importance of an-

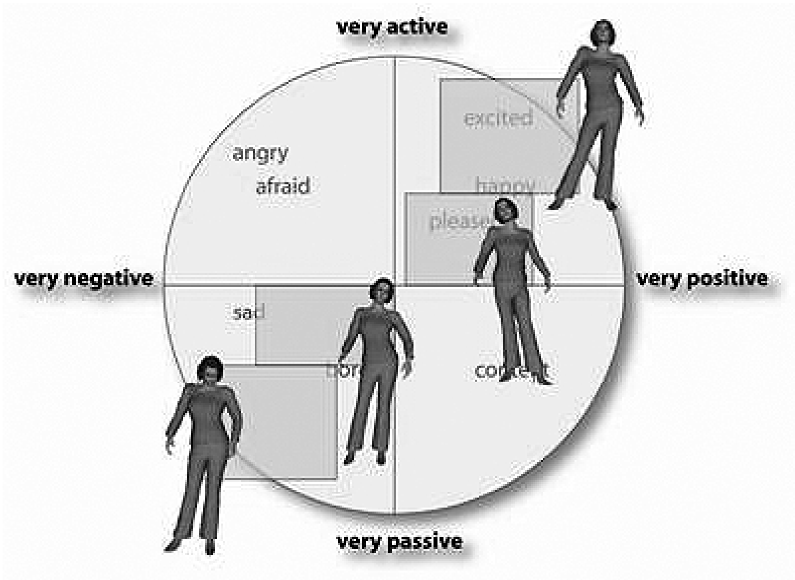

Fig. 2. Emotional idle motions mapped to activation-evaluation disk.

other factor, namely mood is realized recently in simulation of affective states of human being. Mood is a prolonged emotional state caused by the cumulative effect of momentary emotions [108] and is a dynamic property that changes with time. People are often defined to be in good or bad moods and it is possible to have cases such as smiling although being in a bad mood. In [51] a generic model is described for emotional conversational with virtual humans considering personality and mood factors. Using the OCC model of emotions a relation is constructed between the goals, standards and attitudes in the OCC model and personality traits in OCEAN model. For example, an agreeable person can adapt his goals to other people or abandon his goals in favor of others or an open person is prone to fast changes in standards. For the visual front-end the 22 emotions of OCC model is extended with two other emotions surprise and disgust that does not take place in the OCC model and grouped into six basic facial expressions of Ekman. Personality, mood and emotions are used in many applications as a three layer model of personification where mood is considered as a medium-term property between temporary emotions and permanent personality. ALMA (A Layered Model of Affect) [36] aims to provide a personality profile as well as real-time emotions/moods and uses Big Five personality model and OCC emotions. In [90] a platform is developed for dynamic character design for storytelling environments where storytelling players or designers have an affective way of controlling synthetic characters through high-level personality and emotion controlling. In BASIC [2], a believable, adaptable socially intelligent agent is developed that extends the three layer personality model of emotion-mood-personality with memory and social cognitive factors. An application of emotion representation using activation-evaluation space can be found in [7]. In [84] an anthropometric agent, Max is developed whose cognitive functions are modulated with an emotion system and emotional state affect facial expressions, gesture and speech. The underlying emotional system consider emotion, mood and boredom factor that occurs in case of absence of stimuli. As a result of an annoying conversation with the user, Max gets angry with his face, gaze and body and leaves the screen when the user goes on annoying and turns back when he calms down.

Considering the visual front-end of computational systems that contains a personality model, earlier applications started with a 3D talking head capable of facial expressions and speech responding according to the dialogue state and personality model. At the next step, more has to be considered such as effects of emotions on body movements, gaze, voice and physiological signals such as blushing and sweating. Efforts in recognizing the mood of a person are mainly focused on facial and oral cues but body movements are not considered that much. The reason for that are the lack of systematic study on gesture features and the high variability of the possible gestures [70]. Egges [1] presents an animation system which allows the synthesis of emotional balance shiftings according to the emotional state using the activation-evaluation [106] model of emotions (Fig. 2). In [58], a gaze movement model is developed that enables an embodied interface agent to convey different impressions to users. Three parameters from psychological studies is considered in the gaze model: amount of gaze, mean duration of gaze and gaze points while averted. They implement a two state Markov model to implement the gaze model where one state is the gazing state and the other is the averted state [87] describes a two axes emotional speech model. In addition, emotion and personality has proven effects on cognitive processes such as decision making, learning, memory and planning which are concepts studied in different disciplines such as psychology and neuroscience. Our emotions take role as motivational factors for our decisions and effect our actions. When looking at the perspective of autonomous agents, an agent can choose whether or not to pay attention and/or react to a given environmental stimulus according to its goals [20]. The relation between motivations and emotions of a virtual human are simulated in [27]. According to this framework, emotions influence motivations at qualitative levels such as length, perception, activation and interruption.

5. Conclusion

In this paper, we have presented a discussion about the various aspects of designing and modeling virtual human and how intelligent decision technologies can be used in many stages of virtual human architectures. Autonomy, interaction and personification are three important aspects considering both mental state of a virtual human and its interaction with virtual environment and real people. The area has its basis in different disciplines so that successful results in this field is in majority due to good collobaration between different communities. With the many advances in intelligent decision technologies in recent years, these techniques are becoming more important to model the mind of the virtual human as well as analyzing the captured data from the real human and modeling the interaction between virtual and real. Utilizing these techniques for the creation of virtual human will surely light the way for designing more realistic virtual characters in addition to the improvements in computer graphics.

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