Robot Behavior Expression by Illusion of Life

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***Abstract*—From long before, the puppeteers and animators have realized that the trick of behavior expression of the artifacts, such as the marionettes or cartoon characters, is to produce the illusion of life in the audiences. This principle can be applied to behavior design of the social robots that communicate with people through body movements. Accordingly, the emphasis of robot behavior design should be placed on the visual effects that are helpful to produce the illusion of life but not to copy human motion strictly. To produce the illusion of life, the artists give emotions and personalities to the animated film characters while the computer animators add more features like reactivity and adaptation to the interactive figures. The illusion of life produced by expressive behaviors of the robots in social and network environment can be enhanced with human robot interaction.**

***Keywords*— robot behavior, expression, illusion of life**

I. INTRODUCTION

The robots in social environment are often designed to be able to communicate with people through multiple modalities. The purpose of robot behaviors in this kind of application is not for manipulation, but for expression. Body movements are one of the most powerful media that can be used by both human and the robots to convey information. Behavior design and expression of the robots may get inspirations from the ways of motion generation that have been practiced by the puppeteers and animators.

From long before, people working for puppet theaters or film industry have realized that the trick of expression with the artifacts, such as the marionettes or cartoon characters, is to produce the illusion of life in the audiences [1]. Illusion of life refers to people's subjective sense of realism produced by the essential features of the artifacts in motion. Human have the inborn tendency to treat unanimated objected in the same way of treating people when the artifacts share some kinds of lifelike features with human. According to this principle, the emphasis of robot behavior design should be placed on the visual effects that are helpful to produce the illusion of life whether the structures and movements of robots can strictly emulate human or not.

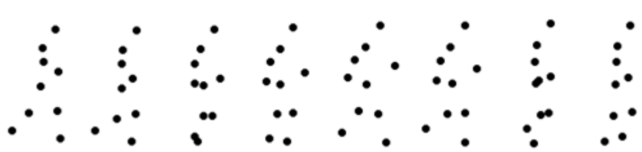

Figure 1. Animated dots produces the illusion of motion

To produce the illusion of life on the animated characters like Mickey and Pluto, the artists from Disney [2] endow them with emotions and personalities. By this way, the audiences watching the films are totally attracted by the life-like animated characters and submerged into the stories. Each frame in (Fig. 1) is composed of several dots. Once made into animation, the frames will let people have the feeling that a man is walking. Twelve rules developed by the experienced animators have become the gospel of animation, and later on they were introduced into 3D computer animation [3]. For the applications in which the interaction between the animated characters and human are critical, the animated characters should process more characteristics in order to produce the illusion of life. Blumberg [4] listed them as reactivity, independence, selectivity, intentionality, responsibility, adaptation, and variability. These augmented features of the interactive animated characters use traditional animation techniques as the means of expression. Philosophical investigation to the illusion of life may refer to the theories of Turing's test and the intentional stance [5].

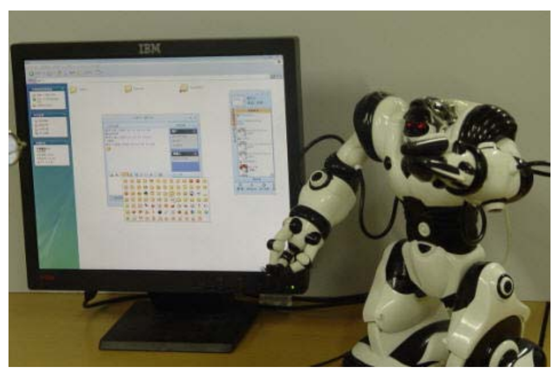

Figure 2. Behavior expression of robot

The behavior design methods that aim at producing the illusion of life are applied to desktop robots that use body movements to enhance conversations on instant messaging, a kind of real-time online communication based on typed text between people (Fig. 2). The desktop robots establish and maintain both social and physical relationships with humans. People use the robots as their avatars that convey the information of the users with expressive behaviors. When a local user input text or emoticons on the client-side user interface of the instant massaging software, the text messages or emoticons are transferred on the Internet and transformed into a series of actions on the desktop robot in front of the remoter user. The desktop robots can transform conversational information into expressive body movements. Like the role of nonverbal cues to interpersonal communication, representing instant messages with the behaviors of desktop robots may enhance the expressive effects of online conversations. To make this kind of human machine interface usable and comfortable, the robots should be able to produce the illusion of life on the users with behavior expression and to make people understand the body movements without difficulties.

II. BACKGROUND.

The applications of social robots range from service, entertainment, education, to psychological therapy. Social robots are the robots mainly designed for the intention of social interaction with human. Their physical bodies and mobility make them into movable human machine interface for information expression in the physical world. A list of robots designed for the purpose of making social interaction to human can be found in [6]. People can use the social robots as their avatars in which the robots act as the representatives for those persons. One example of this kind of applications is the teleoperated robot described in [7] for remote communications that act socially in order to effectively convey information. To represent the information from digital world composed of networks and virtual environments, three robot marionettes with a rich collection of behaviors were built [8]. Their physical bodies are appropriate for making use of nonverbal behaviors in expression. A system using two face robots to make face to face interaction between two persons on network is described in [9]. Another application is to use the robots as social partners of the human. The robots change the behaviors and feelings of humans through social interaction.

The robots often take human and animal forms though they can have any body structure. The humanoid robots resembling human in appearance and behavior have the potential to work for effective social interaction with the human. People incline to anthropomorphize them to make the interaction with them easy and comfortable. Anthropomorphism is people’s tendency to attribute human characteristics to inanimate objects, animals, and artifacts with the view of helping people rationalize their actions. Some humanoid robots have shown extremely compelling demonstrations, such as Honda's child sized ASIMO. An android that emulates the appearance and gestures of a human in high accuracy is made to study the effects of telepresence [10]. The humanoid robots used in behavior research may be the full-body systems, the upper torsos, talking heads, and the robotic dolls. Many face robots have been built to facilitate human robot interaction with affective computing methods [11].

Body movements as a visually observable function of the artifacts can be produced with different motion generation methods. People have explored some methods to make inanimate objects animate in charming manner due to their fascination of producing an artificial copy of themselves [8]. The target artifacts for behavior expression may be puppets on stages, animation characters on films, 3D characters on computers, and robots on desks. Behavior design for the robots in social environment may get inspirations from the practices of puppet performance and animation.

Puppetry can be found in many cultures as a kind of popular art form having a long heritage [8]. A skillful puppeteer can manipulate a marionette to produce complex lifelike behaviors. A large amount of visual information enough to describe a complete story can be delivered to the audiences in the form of nonverbal communication. The puppeteers circumvent the limitations of mechanical structures of puppet figures by producing the illusion of life with the essential features of lifelike movements.

Traditional animation began in early twentieth-century with the growth of film industry. It is created by photographing a series of individual drawings on successive frames to produce the illusion of motion. The animators have noticed that what happens between the frames is more important than what exists on each frame. Animation on computers, whether 2D or 3D, inherits those methods developed for traditional animation. From the many animation techniques, such as keyframe animation, motion capture, non-linear animation, procedural animation, and physical model based animation, the first two methods are most widely applied to character behavior design.

Keyframing and interpolation method is one of the fundamental and standard techniques for character animation. The animator can pose a character by specifying a set of joint variables. The representation of behaviors is the same as choreographing dances. The pose of a character along animation time line is specified by each key frame. Intermediate poses can be generated by the computers using interpolation algorithms between key frames. The animators have full control over motion details and expected effects. Physical or geometrical models of the characters and environment commonly are not required. The major drawback of this method is that the amount of work increases dramatically with the length, complexity and intended realism of the animation. It requires animators to exercise great skills in precise timing among motion of each joint. One concept similar to keyframe in robot motion control is the via point. Breeman [12] uses an animation engine to produce facial expressions on a talking head robot.

Motion capture is a preferred method by film makers to produce expressive movements on animated characters. Robot behaviors may be taken from the human by motion capture and learning. The robots seldom directly replay motion capture data due to the mismatch on body structures between them and the human. There must be a transform involved in the process of implementing human movements on the robots. The transform may be achieved through some learning methods such as imitation. Yamane [13] uses motion capture data from human actors to control a motorized marionette. The motion data needs to be mapped to the target marionette because both the marionette and human actors have different numbers of degree of freedom, body size, mass distribution, constraints and driving power.

Motion capture is commonly regarded as the complement of character animation created with keyframing. The motion data captured from a human performer is enough to replicate the realistic movements but may not be able to reveal the emotions to the audiences through the essential characteristics of body movements.

III. APPEARANCE

The body movements of the desktop robots that are rational in the observer's eyes have better communication effects than fine imitation to human behaviors. This effect can be implemented through endowing the desktop robots with emotion, personality and motivation. Even if the trajectories of the body movements of the desktop robots are not strictly close to those of human movements, information can still be delivered through communication on the level of emotion, personality and motivation. To make the desktop robots become engaging human-machine interface, the design should cover all three levels of communication: appearance, behavior, and emotion.

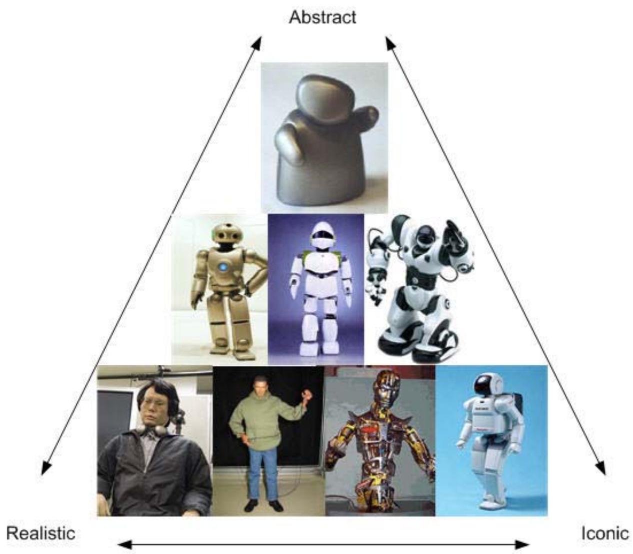

Figure 3. Comparison of robot appearances

The social robots used to express instant messages with behaviors are RoboSapiens (Fig. 1), a kind of toy robots [14] for less than one hundred dollars. The toy robots have a size suitable for acting on the desks. This robot was designed to a biomorphic structure and an artful appearance. The robot has a rather simple mechanical structure with seven DOFs, which are enough for it to produce a rich set of expressive gestures and behaviors for the task of enhancing instant messaging communication. Both the right and left arms can be controlled separately but the position and speed of each joint can not be specified individually. Up to 67 gestures and activities are preprogrammed into the onboard circuit in the chest of the robots, such as lifting right arm, going forwards, grasping, throwing, kicking, sweeping, picking up, dancing, whistling, belching, etc.

In order to act according to conversations and generate more behaviors, the robots have to be controlled directly from a PC rather than the remote controls in people's hands. An infrared transceiver with RS-232 interface is connected to the PC on the serial port to replace the remote control and a driver is written to emulate the waveforms sent out from the remote control. The waveforms from the remote control that can produce all the 67 gestures and activities on the robots are recorded and reproduced by the RS-232 infrared transceiver. Now the robot can be controlled from PC without modifying the onboard circuit if no single joint was required to be controlled directly. More activities may be built on these pre-programmed moves by composing them into sequences.

The desktop robots designed to have human-like or animal-like morphologies help initiate communication and interaction through providing people intuitive and comprehensible social cues. People will treat a desktop robot with human-like appearance differently from a pet robot. Anthropomorphism offers the desktop robot life features that are significant for a machine to be socially engaged. The resemblance on the appearances and behaviors between the physical agents and their natural counterparts causes illusion of life. Hence, it is advantageous to add life characteristics to robot design and implement human-like behaviors on the anthropomorphic, i.e., human-like, body structures. The desktop robot for conveying information to human through body movements obviously belongs to this category. Like [15], a comparison on the appearances of several famous social robots is made in (Fig. 3). The Robosapien robot has a middle level of abstract appearance that is a little iconic.

Appearances of the robots prepare a context for interpreting the body movements and add constraints to behavior design. The behaviors of an anthropomorphic robot are easier to be understood by people if the behaviors are designed to have the features of human behaviors. Movement has more weight than appearance in generating believable performance.

IV. ROBOT BEHAVIOR

A. *Emotional behaviors*

The emotions of the robots are defined with six dimensional arrays in which each component is correspondent to one parameterized emotional state from happiness, anger, disgust, fear, surprise and sadness. To produce the behaviors expressing the emotions, the fundamental rules of character animation are applied to the robots while satisfying their kinematics constraints. Within the twelve rules [2], that is, squash and stretch, anticipation, staging, straight ahead action and pose to pose, follow through and overlapping action, slow in and slow out, arcs, secondary action, timing, exaggeration, solid drawing, appeal, some rules are not appropriate to be used to robot behavior design.

Anticipation can be implemented by inserting an action before the major action is performed. A reset action that lets the robots to take a starting gesture is often used as anticipation to indicate that the robots begin to move with another movement. The robots can move forwards and backwards on the desk to approach or leave the users. A shorter distance between the users and the robots often expresses intimacy or love depending on the context. The timing of movements can be implemented by controlling the speed of the body movements. Faster movements are often associated with anger or excitation feelings while slower movements express sadness or tiredness. It is not appropriate to implement timing effects by inserting inbetweens into the major movements as this will make the resulting movements hard to be interpreted. As one of the major methods to produce the illusion of life, exaggeration in animation makes the movements amusing. Body movements of the robots can be exaggerated with extreme or repeated actions

(Fig. 4). Some subtle postures can be made by the robots, such as to stay inclined.

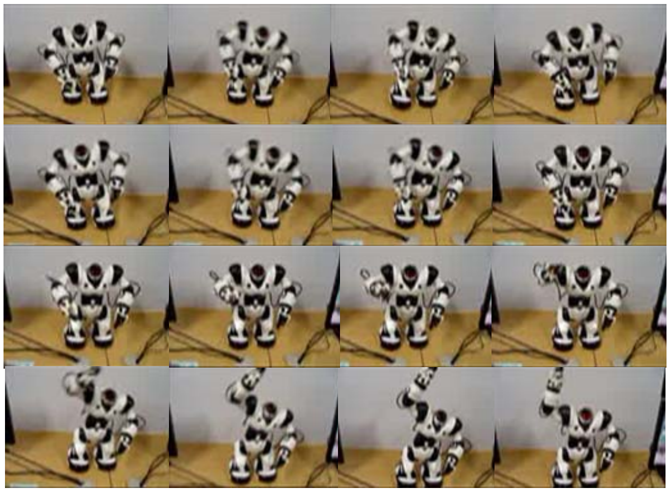

Figure 4. Action generated with animation principles

The rigid bodies of the toy robots do not allow them to be squashed or stretched. Secondary actions are not easy to be expressed on the robots though they can follow the primary actions. The robots have limited number of joints or degrees of freedom. It is difficult for the robots to move along circular and smooth path.

B. *Interactions*

Besides visual expression of robot behaviors, effective interaction with people is another way to produce the illusion of life. The robots used in online communications act as the avatars of the remote users. This application requires the remote users to have full control to robot behaviors in order to make it express the information of the users accurately. The autonomy of the robots is rather limited.

The remote users can directly specify the behaviors of the robots by selecting animated icons that are made of the key frames of body movements. The robots are responsible to transform the key words into body movements when the users input text sentences in the conversations. The body movements are associated with icons and key words manually in a rule-based method. The rationality of the robot behaviors is guaranteed by the remote users. The behaviors specified by the remote users by either selecting icons or inputting text produce the feelings of reactivity. Controlled by the remote users, the robots exhibit some degree of independence to local users. This will let the local users to treat the robots as some things having goals or intentions. Behavior selection of the robots according to the situation is made by the remote users. It may give the local users a feeling that the robots know how to act. The intentionality of the robots is revealed with the body movements. People try to endow some interpretation to all kinds of body movements, even if the robots have no move. In continuous conversations, the input of the local users will get responses from the remote users whose reply is expressed with robot's body movements. For the local users, it seems their messages could always get responses from the robots. The adaptation of the robot behaviors mainly depends on the users who make different text input or icon selection based on the experiences of communications. Variability in movements is one of the major features of human behaviors and helpful to make robot behaviors believable. The users can use different body movements to express similar information.

V. SOFTWARE IMPLEMENTATION

A software that can make online conversations on instant messaging using MSN protocol is implemented. It is a client side program that has dependency on the MSN servers. This program consists of eight modules to accomplish the functions including network communication, message parsing, user input and output, robot motion control, behavior editing, storing, and sharing (Fig. 5). The program was developed in C++ and C# with Microsoft Visual Studio 2005. More than 1000 keywords expressing affective cues are categorized into the six basic emotions.

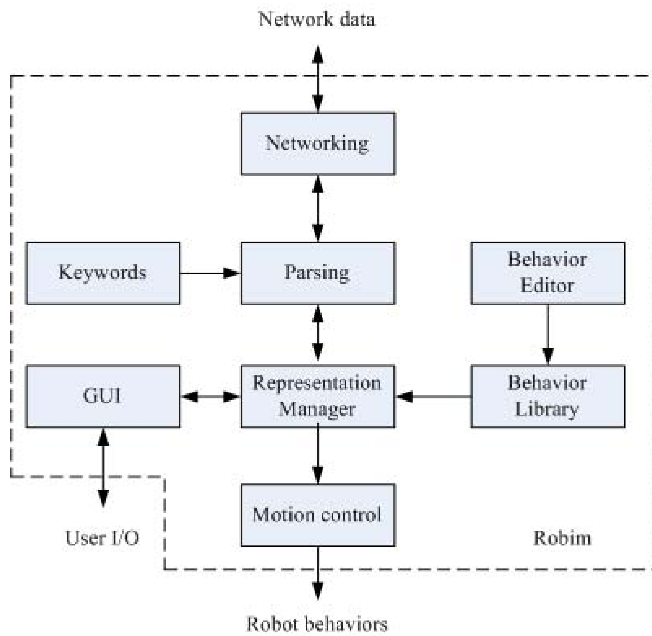

Figure 5. Software composition

The networking module implements MSN protocol that IM client programs use to communicate with each other. It packages the conversational contents into network data stream. The robot motion control module performs low-level motion control to the desktop robots. A list of the infrared waveforms for activating the pre-programmed moves that the robots can perform is coded and saved in a plain text file that records the robot structure. The robot control module reads in the waveforms from the file and writes them to the serial port. The transceiver transforms the waveforms into infrared signals that drive the robots to produce expressive body movements.

The message parsing module examines the received messages and searches for keywords or emoticons that are manually compiled in the tree structure.

The representation manager synchronizes the output of text and image contents to the screen, voices to the sound card, and behaviors to the robot. The text messages and emoticons sent to the users are replaced by robot actions according to the mapping relationships defined in the behavior library.

Behavior Editor (Fig. 6) is designed for common users to create customized behaviors. To minimize the dependency on the specific structure of the robots, this module is designed to have a graphic user interface for operating the available activities but not single joint of the robots in a visualized manner. The parameters for specifying body movements are encapsulated into the behavior modules that are visually represented with emoticons. Each action from the set of behavior modules is represented with an icon and is associated with the constraints that prevent the users from making contradicting combinations with other actions. For example, a walk-forward action may happen with an arm-lifting action at the same time while it conflicts with a walk-backward action if a user tries to make them work simultaneously. Basic behaviors are edited with the key frame method. Some behaviors are exaggerated with repeated actions.

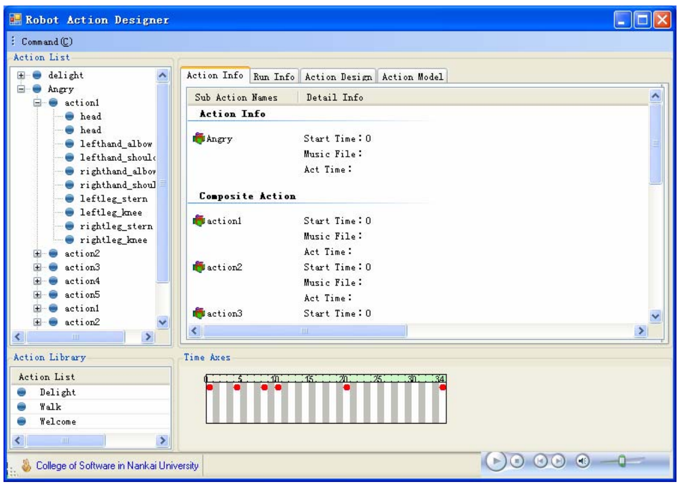

Figure 6. Behavior Editor

With behavior editor, users can design new moves to satisfy their personalized requirements by combining the prepared activities from the set of both pre-programmed action modules and activities designed by others into motion sequences. Without prior knowledge about robot motion control, the users can compose new behaviors by operating the pick-and-place components.

In current behavior library, robots' activities are manually associated with text, emoticons, and icons by the users stored in tree structure. They are stored in XML format, which has better portability. They are synchronized with short pieces of music and intonations.

VI. CONCLUSION

Many different methods and skills have been explored by people to generate motion effects on inanimate artifacts like the puppets and animated characters. One inspiration obtained from these experiences is that the behaviors of social robots should be designed to produce the illusion of life in the audiences. For the application of using desktop robots to enhance online communications though instant messaging, expressive behaviors can be generated with the methods have been used in character animation. Whether the robot behaviors are made as the copies of human behaviors or not, the information from the users can be expressed with body movements.

To express the information of the users accurately, the robots are given a low level of autonomy. Behavior expression is regarded as an enhancement to communication on instant messaging that is based on text. The necessity of the computers may lower the effects of the illusion of life at some degree though the text provides a context for people to understanding the meanings of robot behaviors. Text input and icon selection remind the users that the robots are controlled by other people.

The mechanics and control methods restrict animation techniques to be applied freely to behavior design of the robots whose movements must satisfy the constraints imposed by robot kinematics and dynamics. Even after carefully modifications to the actions, the mechanical body movements can not be as graceful as the puppets or the animated characters.

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