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Emotional Head Robot with Behavior Decision Model and Face Recognition

Ho Seok Ahn[1], Pyo Jae Kim[1], Jeong Hwan Choi[1], Shamyl Bin Mansoor[1],
Woo-Sung Kang[1], Seok Min Yoon[1] , Jin Hee Na[1], Young Min Baek[1],
Hyung Jin Chang[1], Dong Sung Song[1], Jin Young Choi[2] and Hyeong-Seok Ko[3]

[1] School of Electrical Engineering and Computer Science,
Automation and Systems Research Institute,
Seoul National University, Seoul, Korea
(Tel : +82-2-872-7283)
E-mail: [1]{ hsahn,pjkim,jhchoi,shamyl,wskang,smyoon,jhna,ymbaek,hjchang,dssong}@neuro.snu.ac.kr
[2] {jychoi@snu.ac.kr} [3]{ko@graphics.snu.ac.kr}

Abstract: There has been a lot of research for developing intelligent robots that can effectively perform human robot interaction. Our motivation for this research is to develop a robot that can interact with people and assist them in their daily routines, in common places such as homes, super markets, hospitals or offices. In order to accomplish these tasks a robot must be human friendly showing some emotions and exhibiting a friendly character and personality. We present an emotional and behavior based intelligent head robot that performs face recognition, and effectively communicates with people by expressing emotions using a 3D character on its screen. The behavior of the robot depends on its interaction with people. Face recognition capability of our robot is a novel classification method based on Support Vector Domain Description (SVDD). This method allows the system to be trained rapidly and improve the recognition rate gradually by learning face incrementally. For the emotional behavior of the system we implement an emotional behavior decision model that defines the character of our robot and makes different behavior decisions.

Keywords: Emotional Robot, Head Robot, Emotion Expression, Face Recognition

1. INTRODUCTION

Nowadays intelligent robots are at the forefront of technology performing all kinds of tasks imaginable. From household robots to surveillance robots, bomb disposal robots to news casting robots, it is impossible to imagine a world without robots as they have become omnipresent in today's world. Our focus of research is the interaction between robots and humans. As this interaction is increasing every day, we need robots that can communicate with people without letting them feel uncomfortable. For example, one of the applications of an intelligent service robot is an elderly serving robot. Generally older people tend to dislike technology; therefore one of the challenges to design such a robot is to make the robot adaptable and people friendly. This is possible if the robot can exhibit some kind of personality and behavior. Using this concept of personality we have developed a robot that can show different emotions and can change its behavior depending on the situation it is facing.

As more and more robots are being deployed in places where they have interaction with humans, it is necessary to develop robots that can interact in a very human like and friendly manner. Therefore the focus of research these days is development of robots that can express emotions and change their behavior under different situations. MEXI [1] is a robot that can adapt its behavior by recognizing human emotions using human speech. It can not only express emotions but also recognize human emotions using speech synthesizing and accordingly adapt its behavior. WE4R-II [2] can express multiple emotions using its eyebrows, eye movement, gestures and can react to multiple environmental stimuli simultaneously. [3] Lino is a domestic robot with emotional feedback developed to respond to peoples' needs, habits, gestures and emotions. CASIMIRO [4] is a multimodal robot that makes use of vision, voice and gesture recognition to achieve human robot interaction. A similar robot Mertz [5] has been realized by Aryananda that incrementally learns to socialize by interacting with people. All these robots focus on one goal; Socializing with humans to the extent that the humans feel comfortable in their presence and do not feel any hesitation while taking help from them. We have developed our robot with the same goal in mind. By developing an emotional behavior decision model for our robot, we have given a certain character to our robot. It uses its emotional behavior model to behave in different ways depending on different situations, while expressing emotions using a 3D character.

Our PIL Head robot consists of a face recognition system, an emotional behavior decision model, gesture recognition and emotion expression using a 3D character. The goal of our robot is to perform the most efficient form of interaction with people. This interaction is made efficient by a fast face recognition system. Our robot uses an SVDD based classification system for face detection and recognition that has fast training capability. This face recognition system is based on our previous research [6]. The gesture recognition system of our robot can detect hand gestures of a person. These gestures can be interpreted in different ways depending on the application of our robot. The emotional behavior decision model that we have applied on our robot is the most important feature which gives our robot a unique character and personality. This personality is further strengthened by using a woman's face as a 3D character, which communicates with people using lip synchronization and also expresses multiple emotions. This unique personality and the 3D character allow our robot to be identified as having a unique persona.

Our paper is organized as follows. Chapter 2 gives an overview of the head robot architecture. Section 3 explains the emotion expression while section 4 details the face recognition system. Section 5 describes the emotional behavior decision model. In section 6 we discuss our results which show how our robot can change its behavior depending on its interaction with a user. In the final section we describe our future work and conclude the paper.

2. PIL HEAD ROBOT ARCHITECTURE

The architecture of our robot is based on a Pentium 4 CPU for the image processing and emotional model while an ARM based microcontroller for displaying the 3D character on screen and controlling the head movement. The head robot has two cameras for face recognition and gesture recognition. The LCD shows the 3D character of the robot which is used for displaying facial expressions. Fig. 1 shows PIL head robot with its 3D character.

Fig. 1 PIL Head Robot

The purpose of using a 3D character instead of a mechanical head is to make the interaction between the users and the robot more comfortable. With a human face and female voice people can feel comfortable around our Head Robot instead of feeling awkward talking to a machine.

The software architecture is based on an Evolvable and Reconfigurable Intelligent Architecture (ERI) [7]. In this architecture every algorithm is implemented as an intelligent macro core. The system can be easily evolved by adding new IMC's and reconfiguring the arrangement of IMC's. This allows for adding new algorithms into the system as IMC's and improving the performance. In this way we can continually work on the evolution of our robot.

3. FACE DETECTION AND RECOGNITION

For a service robot, one of the most important functions is the face detection and recognition system. As a service robot in a restaurant or in a hospital, a robot must be able to recognize and greet people, while interacting with them. It is important for the robot to maintain a memory of people it has met before so that the next time it sees a familiar person it can recognize him and greet him as a friend. This helps in early adaptation of the robot as a friend of the people instead of being seen only as a machine. Our face recognition system is a fast and incremental learning method which performs swift face recognition and has fast training speed and high accuracy.

We use a novel classification method based on Support Vector Domain Description (SVDD). Our detection and recognition system consists of 3 parts. Image acquisition, face detection and face recognition. For image acquisition we use a web camera. Images from the web camera are fed into the face detection algorithm which uses adaptive boosting [8] for detection of faces in real time. For face recognition we implement a PCA (Principal Component Analysis) based algorithm for dimension reduction and feature extraction, and SVDD based method for feature classification.

Using SVDD allows the system to be trained rapidly and improve the face recognition rate gradually by learning face incrementally. In the case that training data increases, our multi-class classifier based on SVDD can reduce the computational load by training only the data about the class into which new data is added. Fig. 2 shows the structure of our face recognition system.

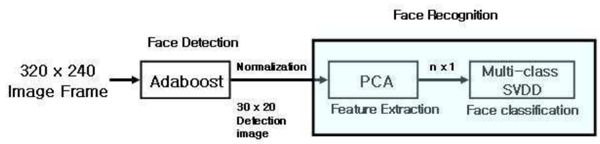

Fig.2 The structure of face recognition system

An image frame is first grabbed from a web camera which is then passed to the face detection system. The face detection detects face from the image in real time by using adaptive boosting. Face features are then extracted using Principal Component Analysis (PCA) which also performs dimension reduction. These features are then used to classify the image as a face by using Support vector domain description (SVDD).

Our face recognition system learns face images rapidly by avoiding repeated use of training data. We use AdaBoost to improve the classification performance of our learning algorithm and cascaded classifiers to reduce computation load by giving different treatments to different kinds of input window. Only input windows that have passed through all the layers of the cascade can be classified as faces. Our face detection and recognition performs fast face recognition, which is one of the basic requirements of our robot. Using this method allows the robot to perform well in real life scenarios where the robot can quickly recognize faces and interact with humans. Most real life applications of our robot require quick face detection and recognition. Our goal is to make the robot perform in as much human like manner as possible. Therefore face recognition in real time is a very important feature that enables us to realize this goal.

4. EMOTION EXPRESSION USING 3D CHARACTER

Different emotions are expressed by the PIL Head Robot using a 3D character on an LCD screen. The character also uses lip synchronization for greeting people. We use a 3D character for emotion expression because a human like face performs a friendlier job than a mechanical head. It is easy for people to adapt to a human face, which also provides our robot with a specific personality and character. A service robot must be easily adaptable by humans. It is a general fact that humans do not usually bond easily with machines or mechanical things, but if a robot exhibits a human-like character and personality then it becomes easy for humans to adapt to. Fig. 3 shows various emotions expressed by PIL Head Robot. Our emotional behavior decision model allows the robot to express happiness, sadness, surprise, love, disgust, fear, anger and respect.

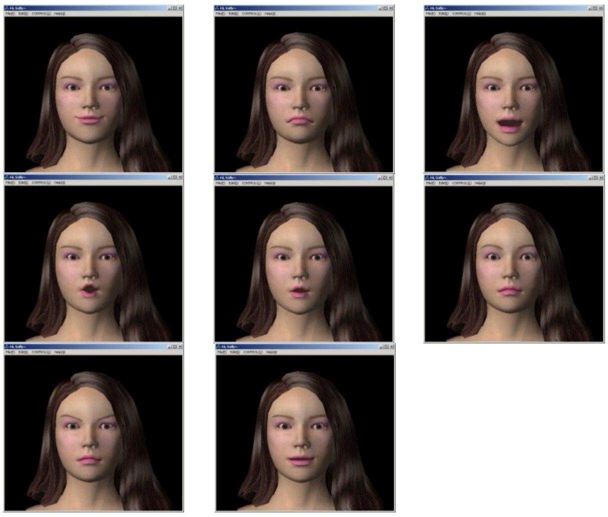

Fig. 3 Various emotions expressed by PIL Head Robot

Using these different expressions the robot can express different behaviors. For example when the robot needs to exhibit sad behavior it can use emotions like sadness, disgust or surprise whereas if it wants to express excitement it can use facial expressions like happiness, love, surprise or respect. Similarly depending on the scenario the robot can use these facial expressions to exhibit anger, apprehension, amazement or joyous behavior.

5. EMOTIONAL BEHAVIOR DECISION MODEL

In human robot interaction, personality is one of the most important characteristics of a robot. It allows the robot to interact with humans in an amicable way, without letting them feel uncomfortable. We have implemented an emotional behavior decision model which provides our robot with its own personality and character. Using this model the robot makes different behavior decisions. The most important feature is its adaptive personality. If personality is altered, then the emotional behavior decision model makes different decisions in unchanged conditions. Fig. 3 shows the structure of the emotional behavior decision model. It consists of five elements; reactive dynamics, internal dynamics, emotional dynamics, behavior dynamics and personality. The emotional model is based on linear dynamic system and has various matrices for personality. If personality of the robot is changed it makes different decisions, although the external stimulus and internal dynamics remain unchanged.

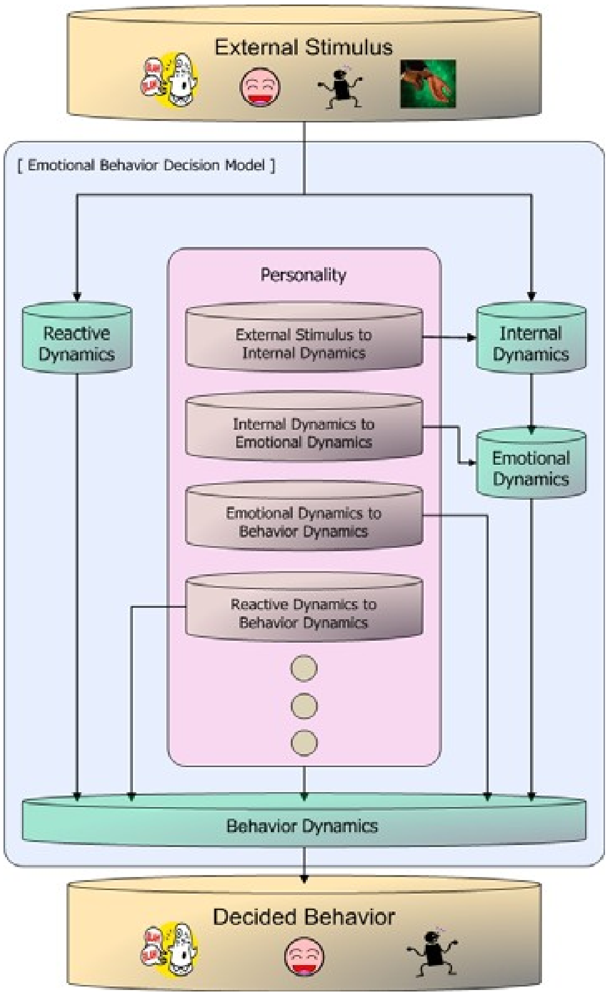

Fig. 4 Emotional Behavior Decision Model

When external stimuli occur, they either affect the reactive dynamics or the internal dynamics. This is decided by the emotional model based on the stimulus. Reactive dynamics allow our robot to react to external stimulus directly without influencing emotional dynamics. For example based on external stimuli the robot may exhibit sadness or excitement. This behavior is observed when the robot can recognize a familiar face. If the face is familiar the robot may exhibit excitement and if it is suspicious the robot may exhibit fear or surprise. External stimuli include face recognition, gesture recognition, speech recognition and other sensors. Internal dynamics in our emotional behavior decision model simulate the effect of consciousness. It identifies whether external stimulus should affect the emotional state of the robot or not. Using internal dynamics the robot can identify whether the stimulus is a joke or if it causes anger. Emotional dynamics depend on internal dynamics and personality. Whenever an external stimulus occurs all elements of the system are recalculated, which also depend on their previous values. That is every element keeps track of its' previous value.

Reactive dynamics, internal dynamics, emotional dynamics and behavior dynamics depend on the personality matrix of the robot. Therefore whenever the personality of the robot is changed, the robot can exhibit a different behavior even though the external environment does not change. The final behavior of the robot is decided by the behavior dynamics. Every behavior has a certain value that changes based on the external stimulus and internal dynamics. For the behavior to be selected from the class of available behaviors, the behavior with the highest current value is selected. There is also a minimum threshold value for the final behavior. If the final decided behavior has a value less than this threshold than the robot does not change its behavior and retains its current state.

The personality of the PIL Head Robot can be changed easily by modifying the personality matrix. Therefore our robot architecture is very flexible and can be applied to multiple application scenarios. For example it can be programmed as a well behaved waiter robot in a restaurant or a friendly teaching robot for children or a ferocious police robot for riot situations.

6. EXPERIMENTAL RESULTS

Our emotional behavior decision model allows the robot to express happiness, sadness, surprise, love, disgust, fear, anger and respect. The current behavior is generated by calculating the affects of the previous state of the behavior model and the current external stimuli. The final decided behavior depends on the previous state, the current external stimuli and the overall defined personality of the robot.

The robot can recognize a familiar person and expresses happiness, while at the same time, it can change its behavior depending on the current interaction with the user. In a typical human interaction scenario our robot can express fear if it sees a human who hasn't treated him nicely previously or it may exhibit happiness if it can recognize a familiar face of a person who treated it nicely. These features allow our robot to behave like a human. As a human being doesn't like being surrounded by people he doesn't like, our robot also feels fear or surprise when faced with someone who does not treat it nicely.

Fig. 4 shows the change in behavior of the robot based on external stimuli. It can be seen that the degree of violence at time 3 seconds is highest as a person is recognized by the robot who used violence. As the person tries to pacify the robot by saying "I Love you", at 9 and 14 seconds, the degree of violence starts decreasing and the degree of attraction starts increasing. At 19 seconds the degree of attraction becomes higher than the degree of violence therefore the behavior of the robot changes. The final behavior of the robot is based on the previous state of the emotional dynamics as well as the current input. The robot decides its final behavior based on the current highest value among all the behaviors.

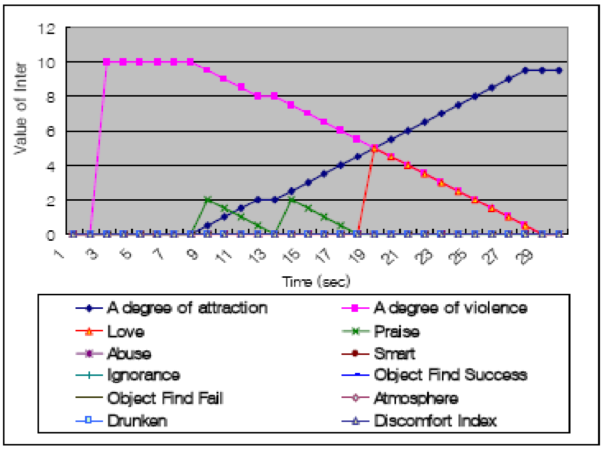

Fig. 4 Behavior change of the robot

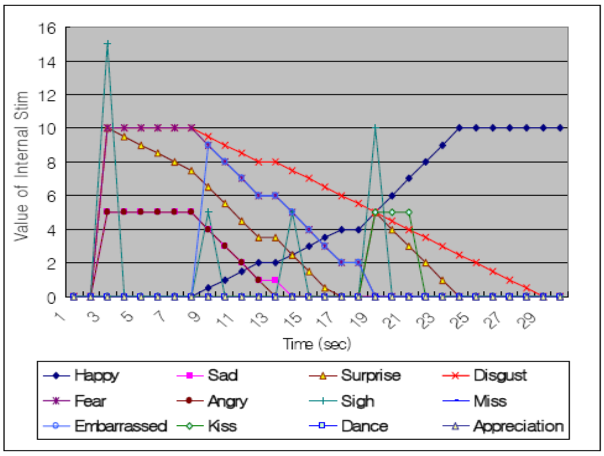

Fig. 5 Behavior decision results

In figure 5 we can see the results of the behavior decision model. At 3 seconds when the person used violence the robot lets out a sigh and feels fear. At 9 seconds when the robot is praised by the person, fear is changed to disgust while in the same interval we can also see that the robot also feels embarrassed. At 9 seconds the value of happiness also starts to increase, which continues as the robot is also praised at 14 seconds. At 19 seconds the value of happiness increases than the value of disgust, and the robot changes its behavior from fear and disgust to happiness.

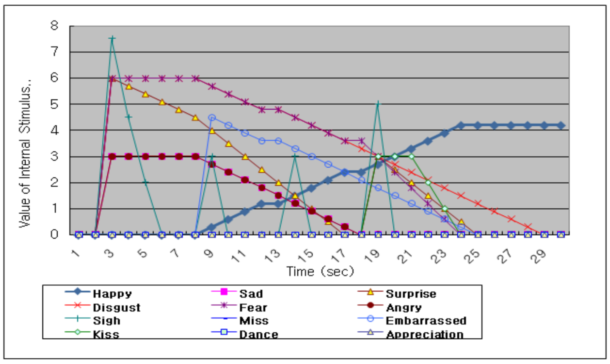

Fig. 6 Behavior decision results

Fig. 6 shows the results of the emotional behavior decision model that has been altered by changing the emotional engine of the robot. This change results in almost the same output, as can be seen by comparing figs. 5 and 6. The only difference we can see is that, the second emotional engine shows less sensitivity to the stimulus values. These results show that we can change the overall personality of the robot by changing the parameters of our emotional engine; therefore PIL Head robot can be used in different scenarios under different application environments.

Based on our results we can say that the behavior of the robot changes while depending on external stimulus as well as the personality of the robot. The robot can express happiness, sadness, fear, anger, disgust, surprise, love and respect based on its current interaction with a person as well as its previous behavior.

7. CONCLUSION

The applications of intelligent robots have changed a lot, as fields such as artificial intelligence have developed over time. Robots have been transformed from being traditional assembly line robots to intelligent robots exploring other planets, defusing bombs, aiding in surgical operations, interacting with people in service areas such as hospitals, restaurants and other public places. Robots are fast becoming an integral part of our society. This integration of robots in our society has been a slow process, but nowadays with the development of new technologies that enable a robot to be highly intelligent, robots are becoming ubiquitous in our society.

In this paper we have presented such a robot that is intelligent enough to adapt its behavior according to the situation and environment it encounters. It interacts with people using a 3D character on its screen and can recognize people using face detection and recognition. The robot is capable of expressing emotions and exhibiting a certain personality using its emotional behavior decision model. The applications of such a robot are tremendous. It can be used in homes as a home service robot, elderly caring robot, a waiter in a restaurant, a nurse in a hospital, a guide in exhibitions or big malls etc. Our focus of research has been the interaction between the robot and people. We have tried to make this interaction between our robot and humans as realistic and friendly as possible. Our results prove that our robot can exhibit multiple behaviors based on its current situation and can change its behavior dynamically if it’s current interaction with a human changes. Therefore the PIL head robot is an intelligent robot that can adapt to different situations and change its behavior accordingly.

In the future we would like to extend the capabilities of our robot by adding object recognition capabilities, detection and tracking capabilities for surveillance as well as other perceptive capabilities to make it more suitable for the numerous applications in the field of human robot interaction.

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