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An Approach of Facial Expression Modeling with Changing Trend in the History of Belief States

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An Approach of Facial Expression Modeling with Changing Trend in the History of Belief States

by

Karamjeet Kaur

A Thesis

Submitted to the Faculty of Graduate Studies
Through Computer Science
In Partial Fulfilment of the Requirements for
The Degree of Master of Science at the
University of Windsor

Windsor, Ontario, Canada

2016

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September 21st 2016

DECLARATION OF ORIGINALITY

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ABSTRACT

An Embodied Conversational Agent (ECA) is an intelligent agent that interacts with users through verbal and nonverbal expressions. When used as the front-end of software applications, these agents provide online assistance that transcends the limits of time, location, and even language. To help improve user experience, there is an increasing need to make ECA more realistic, which can be achieved by using more naturalistic facial expressions.

The proposed thesis research is going to work on the modeling of facial expressions based on the changing trend in the history of belief states and fuzzy logic. This work enhances the software customization system developed previously in our research group with a modification that links the changing value of belief states with the change of emotion expressions at both the mode and scale levels. In addition, the operation of the proposed method is implemented in an online bookstore system, and its success is verified with a usability study.

DEDICATION

To the almighty God, my parents Surinder Singh and Sukhwant Kaur, brother Anmol and my sisters.

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LIST OF ABBREVIATIONS/SYMBOLS

HCI	Human-computer Interaction
ECA	Embodied Conversational Agent
COCOM	Contextual control modes
POMDP	Partially observable Markov Decision process
DWT	Discrete Wavelet Transformation
FLS	Fuzzy Logic System
ESV	Emotional state vector
OCC	Ortony Clore and Collins
FLAME	Fuzzy Logic Adaptive Model of Emotions

CHAPTER 1

Introduction

1.1 Introduction to Human Computer Interaction

Human-computer interaction (HCI) is a discipline concerned with the design, evaluation and implementation of interactive computing systems for human use [18]. The motivation for HCI research is to make communication between humans and machines more efficient and effective. The study of efficient machine interfacing is essential to developing natural and intuitive human-machine communication [51]. This field of research led to the evolution of different software and hardware that we use in our day-to-day life. Creating interactive graphical user interfaces has been one of the persisting goals and became one of the important branches of HCI [56]. New user interfaces for the software applications should be designed to support the performance and experience of its users, allowing them to perform their tasks effectively, efficiently, and with the highest possible satisfaction. For example, embodied conversational agents (ECAs) as a front end of software applications have become one of the massive branches of HCI research.

The main goal of HCI research is exploring how to design the computer to help people complete the necessary tasks more safely and efficiently. With the development of high-speed processing chips, multi-media and Internet Web technologies the late 1990's saw the rapid development and popularization of human-computer interaction research, which has focused on intelligent interactive, multi-modal-interactive multimedia, and virtual HCI technology [55].

- Areas covered under HCI [45].

- ✦ **Computer Science**
- ✦ Psychology
- ✦ Communication
- ✦ Education
- ✦ Health Informatics
- ✦ Design (e.g. graphic and industrial)
- ✦ Gaming
- ✦ E-commerce etc.

As the research is focused on computer science only, the aim of my research is to, therefore, study the user experience of Embodied agent interfaces. Thus the research identifies and investigates the various factors that contribute to or detract from useful, usable and enjoyable interfaces from users' points of view.

1.2 Overview about Embodied Conversational Agents (ECAs)

Embodied conversational agents are referred as virtual conversational humans. It is a form of a graphical user interface with a 2D or 3D human object that interacts with the user through text, voice, gesture, and another input type. Embodied agent, such as, the Microsoft Agent can be used in an enterprise for day-to-day applications to enrich the HCI and experience. These agents wear a realistic human face and communicate with users in social situations, such as an e-learning system, healthcare systems, e-retail environments, and games. These embodied agents primarily have an interface that is backed up by a suitable dialogue manager and knowledge base. The ECAs have several human-like characteristics that include voice animated speech with lip and facial expressions; eye, head, and body movements that realize gestures; expressive emotions; and performative actions, such as displayed listening or thinking postures [56].

ECAs have been made more realistic by incorporating adequate facial expressions. There are different techniques available for facial expression modeling, but accuracy in providing efficient expressions to the user as an output is still lacking. The embodied agents show their intellectual and cognitive capabilities by means of action selection that is based upon knowledge and response generation with synchronized multimodal outputs [56]. In the areas of computational synthetic agents, emotions have received much attention for their influences in creating believable or realistic, human-like characters [42].

1.3 Significance of Facial Expressions in an ECA

Facial expressions are one of the most important sources of information about the emotional state. Researchers are paying a great attention towards the importance of facial expressions of a 3D animated face to express the emotions in a natural way but still a wide area of research [13]. Creating the facial expressions of agents requires usually significant time, specific knowledge and skills. This is especially true because synchronization of gestures based on input from the user is essential in embodied agents; thus, animators spend an enormous amount of effort to achieve this. Creating a system that consists of embodied agents with facial expressions could help users to interact with the existing text based without facial expressions systems more effectively [10][51]. The aim of this thesis is to generate facial expressions in ECA and uncover how these kinds of applications can be tested by using techniques of the usability study.

1.4 Testing of HCI by Usability Study

A usability study is the testing technique that takes different aspects into the count to measure the usability of systems and the key technique to test HCI. The purpose of usability testing is to find problems and make recommendations to improve the utility of a product during its design and development. To develop effective interactive multimedia software, dimensions of usability testing are classified into these general categories: performance effectiveness, easiness, error tolerance, system integrity, and user satisfaction [33]. The dimensions and other methodologies of usability testing can vary according to the type of application. This thesis uses an online survey for usability study to test the proposed application on online bookstore system and overcoming the limitations of previous usability studies in testing ECA with facial expressions as compared to without facial expressions.

1.5 Motivation

Over the years, significant research in HCI has led to the emergence of different techniques for creating ECAs with facial expressions and improved user interface for software applications. Following research areas can provide insight into these software applications:

1. Research on the effect of realistic 3D Animated Embodied agent on decision-making
2. Research on the facial expression Modeling techniques
3. Research on the 3D faces modelling and facial expressions animation.
4. Research on the use of Fuzzy logic and wavelet transformation algorithms and POMDP belief-state history to predict right facial expressions and scaling

An extensive literature review was unable to find a system in existence that combined the above research categories to design an ECA. There is definitely a need to create a robust system that combines the above categories and could be used in any domain, such as in the online bookstore domain. The objective of the system will be to provide more suitable customer service by understanding the customer needs and intentions.

The embodied agents who are represented by an animated talking head must be expressive; the minds of agents should not be restricted to model reasoning, intelligence and knowledge but also emotions and expressions [19]. According to Bui et al. [10], it is necessary to pay attention not only to the agent's capacities for natural language interaction but also to its non-verbal aspects of expression such as facial expressions. Therefore, this motivated us to create a system that has ECA with primary facial expressions and particularly based on the previous work of our research group we are generating facial expressions with fuzzy in this thesis.

1.6 Problem Statement and Solution Outline

ECAs are receiving significant attention from multi-agent and HCI research societies. Many techniques have been developed to enable these agents to behave in a human-like manner. In order to do so, they are simulated with similar communicative channels as humans. Moreover, they are also simulated with emotions [42]. The accurate modeling of the emotions of an agent, changes to emotional facial expressions and impact on decision-making has long been the subject of extensive research [2] [4] [7] [47]. In this work, we focus on the issue of expressing emotions for embodied-agents. We present a three-dimensional face with the ability to show facial expressions and naturally express emotions while interaction with user. This

thesis will demonstrate a new cognitive model of facial expression generation that will overcome the limitations of existing methods. Through software, we have created a system with an ECA as the user interface, and which has facial expressions. These facial expressions are obtained by using the values of History of belief state trend analysis and Rewards given to the system based on each action. These result values are derived from the previous work of our research group, and used as an input in our system by using the fuzzy logic technique for predicting and scaling the emotional facial expressions. This application will be used for an online bookstore domain for experimental work.

1.7 Thesis Contributions

There are three contributions made in this thesis. First, prediction of emotional facial expressions on 3D animated ECA based on trend analysis of the history of belief states information and fuzzy logic and adding the ECA with facial expressions to the overall system. Second, scaling of the emotions of an agent based on input (observation) received from the user. Third, proved the impact of an effective ECA with facial expressions on the user, by comparing the existing system which is text based and do not have facial expressions to the proposed ECA system. This thesis work is overcoming the limitations of previous usability studies by considering the more than 100 participants in study as compared to previous studies which has range between 22 to 50 and also the participants from different fields and level of study is the evidence of a valid data collection as compared to the data from one or two fields only. Detailed explanation is provided in *chapter 5 and 6*.

An ECA with facial expressions will improve the human-computer interaction by providing different emotions to a user for the better interaction. It provides an

interface to users which are more friendly and interactive in nature, thus improving the overall user experience. To prove the improved interaction by the proposed system (ECA with facial expressions) usability study is the evidence.

A usability study will be conducted on real users to compare the existing text-based system (without facial expression of ECA) and the proposed system (with facial expressions of ECA), and to check whether the proposed system enhances the user experience.

1.8 Thesis structure

The rest of the thesis is organized as follows. Chapter II is the Preliminary which contains all the topics and definitions related to Dialog management techniques, Discrete wavelet transformation, and fuzzy logic concepts which are used further in the literature review and proposed method chapters , Chapter III is the Literature survey that provides comprehensive insights into the existing emotion models and highlights its pros and cons. It also provides a review of the facial expression modeling or emotion modeling approaches and limitations of the existing techniques. Chapter IV explains the proposed method in detail highlighting the new approach for modeling emotional facial expressions of ECA by using the Fuzzy logic technique. Chapter V details the implementation and analysis of the proposed method by a usability study. Finally, Chapter VI will review the results of the usability study, and Chapter VII concludes the thesis with some recommendations and future work. The Appendix will contain some extra information about thesis work.

CHAPTER 2

Preliminary

2.1 Overview

This chapter introduces the definition of the dialogue management system and dialogue management techniques like POMDP (Partially observable Markov's Decision Process), Four Contextual control modes COCOM, Discrete Wavelet Transformation (DWT), an overview of Fuzzy logic and discusses the basic concepts related to this thesis.

2.2 Dialog Management System

Dialog management is a user interface technique that is an interface between the user and the embodied agent. It helps us to accomplish two key tasks:

- Update the context of situations by processing data and deciding what to do next.
- It is an interface between statistical/computational models and users requests

Dialogue management systems also maintain a dialogue history, which stores and updates the dialogue states, and makes decisions about required actions so as to control the flow of dialogue conversation between the user and the machine [56].

2.3 Dialog Management techniques

2.3.1 POMDP

2.3.2 COCOM

2.3.1 POMDP: POMDP stands for Partially Observable Markov Decision Process which is an extension of the Markov Decision Process. A POMDP is an 7 tuple set $\langle S, A, T, R, \Omega, O, \gamma \rangle$ where

- S is the set of states
- A is the set of actions
- T is the set of conditional transitions between states
- R is the reward function
- Ω is the set of observations
- O is the set of conditional observation probabilities
- γ is the discount factor.

POMDP is generally used in the decision making where the outcomes are determined partly random and by the decision maker. The goal of the POMDP method is to maximize the reward function which is known as optimal policy [23].

The equation for belief state is:

$$\begin{aligned}
 b'(s') &= P(s' | o', a, b) \\
 &= \frac{P(o' | s', a, b) P(s' | a, b)}{P(o' | a, b)} \\
 &= \frac{P(o' | s', a) \sum_{s \in S} P(s' | a, b, s) P(s | a, b)}{P(o' | a, b)} \\
 &= \frac{P(o' | s', a) \sum_{s \in S} P(s' | a, b, s) b(s)}{P(o' | a, b)}
 \end{aligned}$$

POMDP Policy: Policy in POMDP is the linkage between state and correspondence action.

An optimal POMDP policy maps belief states to actions.

POLICY: belief \rightarrow action

Belief State: Belief State is a probability distribution over all possible states which give as much information as the entire action-observation history.

2.3.2 COCOM

Contextual Control Model (COCOM) is used to control and analyze team behaviour based on cognitive modes. The focus is how the choice of next action is controlled rather than on whether certain sequences are more proper or likely than others. There are four different modes for the control [53] these are as follows:

a) Scrambled

The choice of next action is completely unpredictable. Scrambled mode is a situation where do not know what to do.

b) Opportunistic

The next action is chosen from the current contest alone based on the salient features rather than on more durable intentions or goals. It involves little planning or anticipation, perhaps because the contest is not clear.

c) Tactical

It involves planning which influenced Performance. Hence more or less it follows a known procedure or rule. Planning is however of limited scope.

d) Strategic

The strategic level should provide a more efficient and robust performance. The person considers the global context, thus uses a wider time horizon and looks ahead at higher level goals.

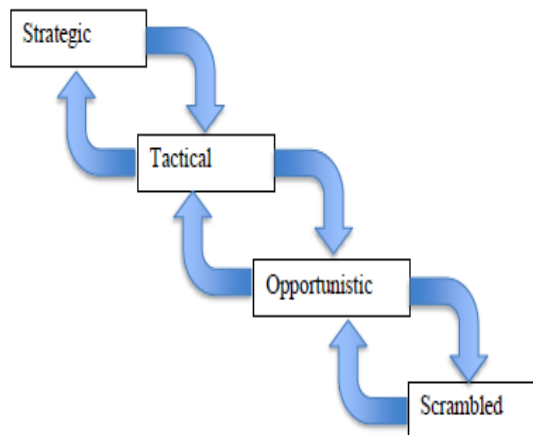


Figure 1: Internal structure of Contextual Control Model [53]

In this thesis we are using these 4 COCOM modes as shown in Figure 1 to predict the emotional facial expressions. Details are given in the Proposed Method chapter 4.

2.4 DWT (Discrete Wavelet Transformation)

Theory of wavelets is mathematical transformations that are applied to signals to obtain the more information from the signal that is not readily available in the raw signal. The information that cannot be readily seen in the time-domain can be seen in the frequency domain.

Raw signal can be combined with the mother wavelet sample. The wavelets are of two types CWT (Continuous wavelet transformation) and DWT (Discrete Wavelet Transformation) [1] [49].

$$CWT_X^{(w)}(T, s) = (1/\sqrt{s}) \int (x(t) \cdot \Psi^*((t-T)/s)) dt$$

- T - Translation(tau)
- s - scaling
- $(1/\sqrt{s})$ - Constant(energy normalization purpose)

- $\Psi^*((t-T)/s)$ - mother wavelet
- $\text{loop}(s=1, s=\text{finite}, \text{time}+=\text{tau})\{\text{CWT}_X^{(w)}(T, s)\}$

DWT (Discrete Wavelet Transform) can be defined as executing CWT in discrete interval of time. We can do trend analysis on the given values by using DWT.

2.5 Overview of Fuzzy Logic

A fuzzy logic system (FLS) can be defined as the nonlinear mapping of an input data set to a scalar output data [38]. Fuzzy logic is a form of many-valued logic in which the truth values of variables may be any real number between 0 and 1, considered to be "fuzzy" [36]. A FLS consists of four main parts: fuzzifier, rules, inference engine, and defuzzifier. These components and the general architecture of a FLS are shown in Figure 2.

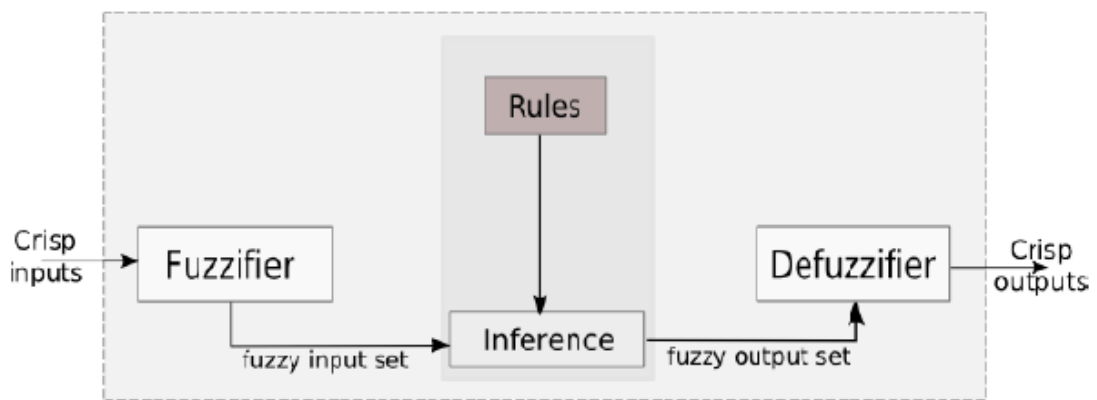


Figure 2: Fuzzy logic system [26]

The process of fuzzy logic is explained in the algorithm 1: Firstly, a crisp set of input data are gathered and converted to a fuzzy set using fuzzy linguistic variables, fuzzy linguistic terms and membership functions. This step is the fuzzification. Secondly, the inference is made based on a set of rules. Lastly, the resulting fuzzy output is mapped to a crisp output using the membership functions, in

the defuzzification which is the last step. All definitions related to FLS and algorithm is as follows [38]:

Algorithm 1: Fuzzy Logic algorithm [38]

1. Define the linguistic variables and terms (Initialization)
2. Construct the membership functions (Initialization)
3. Construct the rule base (Initialization)
4. Convert crisp input data to fuzzy values using the membership functions (fuzzification)
5. Evaluate the rules in the rule base (Inference)
6. Combine the results of each rule (Inference)
7. Convert the output data to non-fuzzy values (de-fuzzification)

Linguistic Variables

Linguistic variables are the input or output variables of the system whose values are words or sentences from a natural language, instead of numerical values. A linguistic variable is generally divided into a set of linguistic terms [38].

Membership Function

A membership function (MF) is a curve that defines how each point in the input space is mapped to a membership value (or degree of membership) between 0 and 1. The input space is sometimes referred to as the *universe of discourse*, a fancy name for a simple concept [27]. Membership functions can have multiple different types, such as the triangular waveform, trapezoidal waveform, Gaussian waveform, bell-shaped waveform, sigmoidal waveform and S-curve waveform. The exact type depends on the actual applications. For those systems that need significant dynamic variation in a short period of time, a triangular or trapezoidal waveform should be recommended [5].

Fuzzy Rules

In the fuzzy logic system, a rule base is constructed to control the output variable. A fuzzy rule is a simple IF-THEN rule with a condition and a conclusion [17].

For example: Let temperature (t) is the linguistic variable which represents the temperature of a room. To qualify the temperature, terms such as “hot” and “cold” are used in real life. These are the linguistic values of the temperature. Then, $T(t) = \{\text{too-cold, cold, warm, hot, too-hot}\}$ can be the set of decompositions for the linguistic variable temperature. Also, the fuzzy rules can be defined as follows:

1. IF (temperature is cold OR too-cold) AND (target is warm) THEN command is heat
2. IF (temperature is hot OR too-hot) AND (target is warm) THEN command is cool
3. IF (temperature is warm) AND (target is warm) THEN command is no-change

All the concepts and definitions provided in this preliminary chapter will be used in the related work chapter and also in the proposed method chapter.

CHAPTER3

Background and Related Work

3.1 Overview

This chapter surveys the various topics related to the thesis.

3.2 Background work on emotions

The study of emotions is a complex subject that involves with psychology and physiology; a few models have been developed. We are discussing few emotion theories and also few other theories which prove that facial expression modeling or emotion based 3D animated embodied agent's gives the impact on User experience.

3.2.1 Basic Emotions

Name	Definition
Anger	'A strong feeling of annoyance, displeasure, or hostility.'
Disgust	'A feeling of revulsion or strong disapproval aroused by something unpleasant or offensive.'
Fear	'An unpleasant emotion caused by the threat of danger, pain, or harm.'
Happiness	'Feeling or showing pleasure or contentment.'
Sadness	'Feeling or showing sorrow; unhappy.'
Surprise	'A feeling of mild astonishment or shock caused by something unexpected.'

Table 1: Representation of Basic Emotions Proposed by Ekman's Theory [8]

The six basic emotions Ekman defined in 1972 are shown in table 1, along with definitions drawn from the Revised Second Edition of the Oxford Dictionary of English, printed in 2005. There is some work that has been done by the psychology researchers on emotions that are as given below:

Researchers	Basic Emotions
Plutchik	Acceptance, anger, anticipation, disgust, joy, fear, sadness, surprise
Ekman, Friesen, Ellsworth	Anger, disgust, fear, joy, sadness, Surprise
Frijda	Desire, happiness, interest, surprise, wonder, sorrow
Izard	Anger, contempt, disgust, distress, fear, guilt, interest, joy, shame, surprise
James	Fear, grief, love, rage
Mowrer	Pleasure, Pain
Oatley and Johnson-Laird	Anger, disgust, anxiety, happiness, Sadness

Table 2: Basic emotions distinguished by Researchers [28]

3.3 Emotions Models

Emotions are internal state of mind that could be affected by any external stimuli. For example smile, emotions arise in a situation when the user is able to fulfil his/her goals and sad emotions arise when a user is not able to fulfil his/her goals. However, emotions are very complex to model. There are few models for emotions that have proven to be effective when dealing with machines. Those emotional models have been created based on the psychological theories of humans. There are so many theories of emotion that it is hard for a computer scientist to choose an

appropriate one to follow when implementing emotions. Moreover, there are continuous debates among the proponents of different views on emotions about the correctness of these theories [10].

Some of the famous models for emotions are:

- a) Plutchik's wheel of emotions
- b) Millenson Model of Emotions
- c) Ortony Clore and Collins Model for emotions (OCC)

3.3.1 Plutchik's wheel of emotions

Robert Plutchik constructed and classified emotions based on certain hypothetical postulates. He established the Plutchik's wheel of emotions in the year 1960. It can be treated as one of the first models of emotions that came into existence, even before the OCC model for emotions.

Plutchik proposed some basic postulates for his emotional theory [48]:

- A small number of pure or primary emotions.
- Primary emotions are different from each other from the prospective of both physiology and behaviour.
- Primary emotions in their pure form are hypothetical constructs or idealized states whose properties can only be inferred from various kinds of evidence.
- Primary emotions can be conceptualized in terms of pairs of polar opposites.
- Each emotion existing in different degrees of intensity or levels of arousal.
- Except primary, all other emotions are mixed that is, they can be synchronized by various combinations of the primary emotions.

Plutchik's emotional theory has been one of the oldest and well-known models for emotional theory, but it has not found its application in embodied conversational agents. The model classified the emotions as a combination of different primary

emotions but never explained how it can be applied to generic computational models that can acquire emotions.

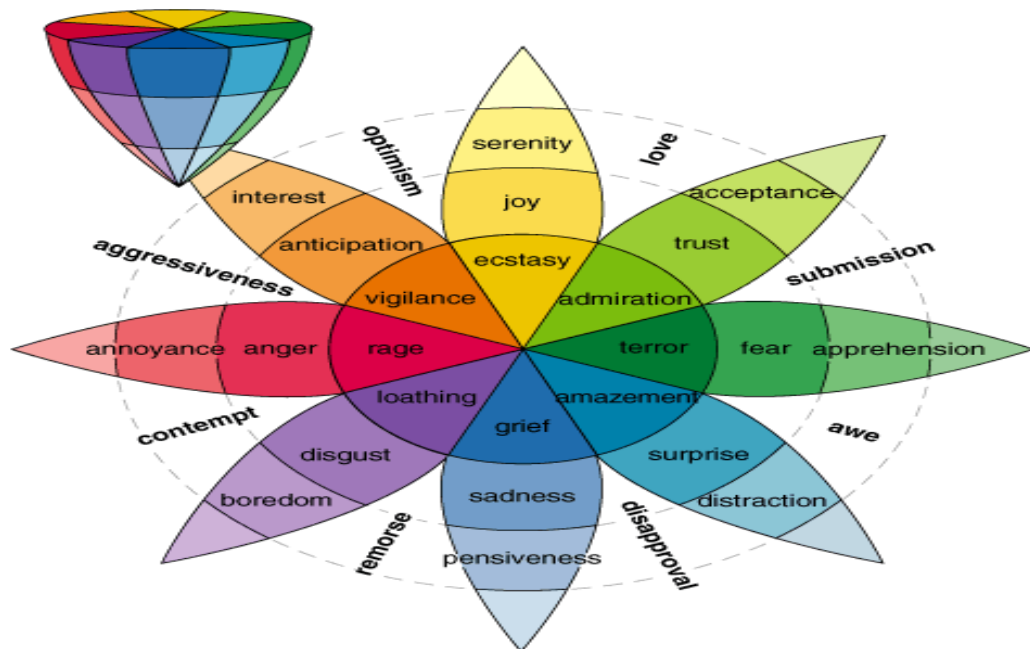


Figure 3: Plutchik’s Wheel of Emotion [48]

The main point to be noted here is the Plutchik’s emotional theory was a research on the emotions itself rather than a research on how to apply these emotions to computational models. Hence, it is more convenient to choose a different emotional model that can be applied to embodied conversational agents.

3.3.2 Millenson Model of Emotions: In his model, Millenson presents a three-axis representation of the emotional state. Along each axis, he places what he considers being a basic facet of the emotional experience. He isolates three emotional factors which he believes represent the sum total of human emotion; the axes being labelled anxiety, elation, and anger. Millenson considers that these three emotions cannot truly represent emotional experience in explicit terms, he extends the behavioural analysis based on two key ideas. First, some emotions are indistinguishable from each other, or

hard to recognize if both are present at same time and save in terms of their relative intensities. Second, the emotions he presents are basic emotions, and other emotions are simply compounds of these emotions. A millenson based approach has been used by researchers towards emotion modelling but not in any ECA emotion modelling. [7].

The nine emotions Millenson lists as fundamental are divided into three groups, one group per axis, and can be summarized as follows:

Anger Axis

Annoyance

Anger

Rage

Anxiety axis

Apprehension

Anxiety

Terror

Elation axis

Pleasure

Elation

Ecstasy

Name	Definition
Annoyance	‘The feeling or state of being annoyed; irritation.’
Anger	‘A strong feeling of annoyance, displeasure, or hostility.’
Rage	‘Violent uncontrollable anger.’
Apprehension	‘Anxiety or fear that something bad or unpleasant will happen.’
Anxiety	‘Feeling or showing pleasure or contentment.’
Terror	‘Feeling or showing sorrow; unhappy.’
Pleasure	‘A feeling of happy satisfaction and enjoyment.’
Elation	‘Great happiness and exhilaration.’
Ecstasy	‘An overwhelming feeling of great happiness or joyful excitement.’

Table 3: Representation of Basic Emotions Proposed by Millenson’s Theory [8]

3.3.3 Ortony Clore and Collins Model for emotions (OCC)

OCC model for emotions is one of the most renowned models for emotions. This model was published in 1988 by Ortony, Clore and Collins in their book “The Cognitive Structure of Emotions”. This model was one of the first models for emotions that could be applied to machines and embodied conversational agents. It was constructed based on the psychological theories of humans. The 22 types of emotions are classified in OCC model are which are Pleased, Displeased, and Happy for, Gloating, Pity, Satisfaction, Fears, Relief, Disappointment, joy, Distress, Pride, Shame, Admiration, Reproach, Gratification, Remorse, Gratitude, Anger, Love, Hate. It defines the rules for generation of emotions. In addition, the OCC theory was never intended to account for models of the consequences of emotion: the original aim of the model was to support inferences about other agents’ emotions. Thus an exclusive reliance on OCC limits the scope of the resulting model, and/or involves ad hoc

approaches to modeling the aspects of affective processing that OCC does not address; most notably the consequences of emotions, or emotion effects: on cognition, on expression and on action selection behaviour [9].

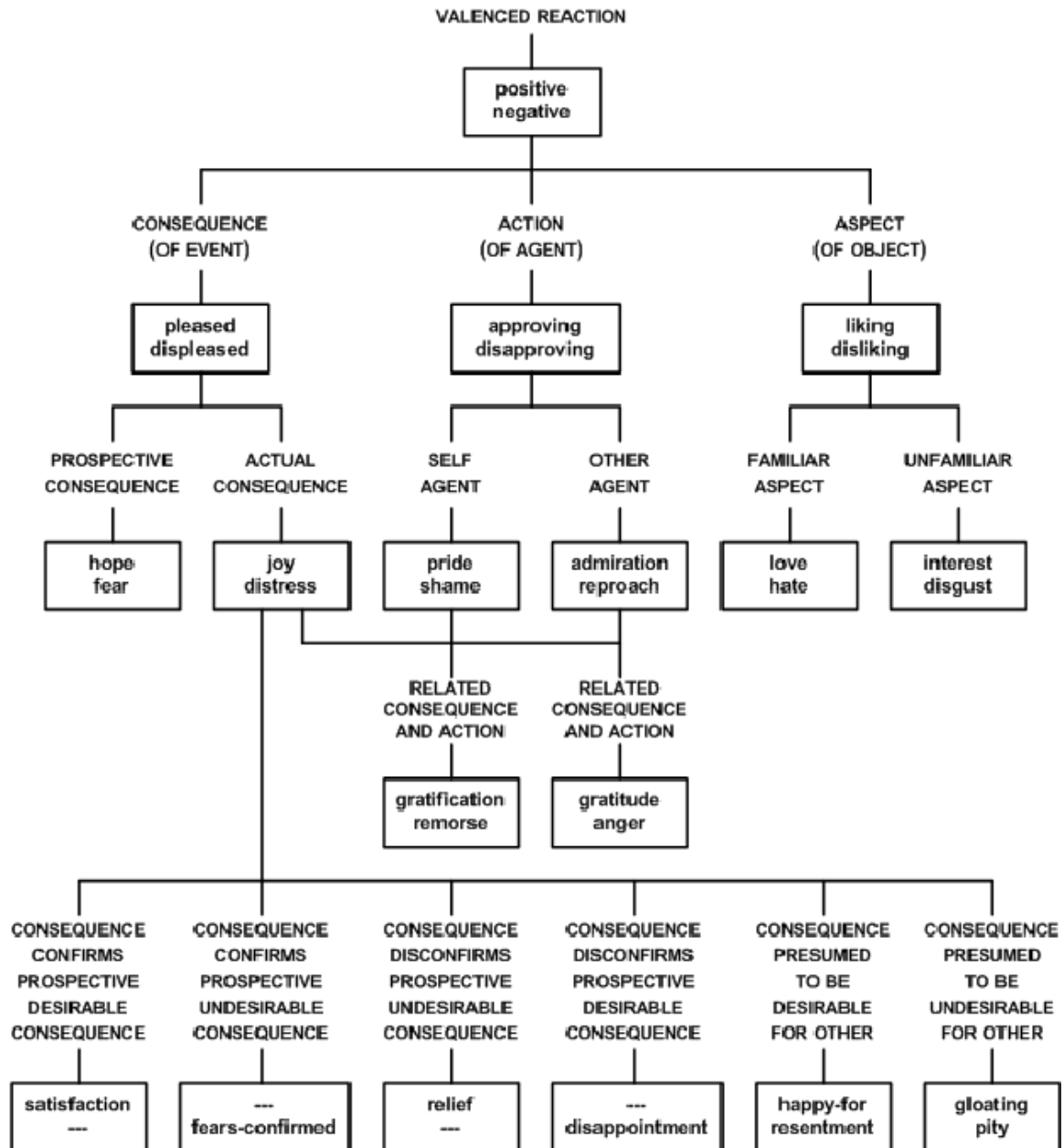


Figure 4: The OCC model for emotions [44]

Researchers have proposed different types of emotion models. Many signs of progress have been made in modeling emotion for virtual humans or ECA's. However, there are still problems we should solve to. For example, the famous OCC

model as shown in Figure 4 provided the best categorization of emotions available, and gave a potential reasoning process but it did not support details of generating emotions [36].

3.4 Impact of an Embodied Agent's Emotional Expressions on Decision-making

According to the recent research in [14], perception and theory of mind reveal that people show different behaviour when engaged in decision making with computers or virtual agents when compared to humans. This kind of research is providing us an important fact for affective computing because they suggest people's decisions can be influenced differently according to believes that emotional expressions shown by computers or embodied conversational agents are made up of algorithms. The results [14] showed that such perceptions have a deep impact on people's decisions. The Participants of the experiment [14] also showed less anger towards ECA and formed more positive impressions of ECA when compared to real agents.

Research on emotion modelling is still a very meaningful subject in many fields because human decision mostly includes fuzzy information. ECA is entirely graphic entity generated by computer and is used to simulate actions of the human while interacting with the system. Emotions are an essential part of human life; they influence how human's think, adapt, learn, behave, and how humans communicate with others. Therefore, Emotion plays a critical role in creating believable and interesting virtual human. Lots of progress has been made in modelling emotion for ECA's. However, there are still problems we should solve to. For example, the famous OCC model as mentioned in section 3.3.3, provided the best categorization of

emotions available, and gave a potential reasoning process but it did not support details of generating emotions. Hence, it proves that emotions have an influence on decision-making processes and emotions are fuzzy in nature which is still a wide area of research [36].

3.5 Impact of an Embodied Agent's Emotional Expressions over Multiple Interactions

An embodied agent (Rachael) has been created [12] to simulate a health professional and attempts to help people improve their fruit and vegetable consumption. The effects of embodied agent emotion on users over a seven-week online study have been examined in which Participants interacted with either an emotionally expressive or unemotional embodied agent. A 25-year old female was used to record the utterances to ensure the voice matched the approximate age of the agent. The agent was, therefore, able to express emotion through both facial expressions and recorded speech. Different versions of the agent like with and without emotions were developed to test how user perceptions changed over an intervention period of 49 days about an agent, and how this, in turn, its impacting the consumption of vegetables.

Two different versions of the agent were developed—an emotional and unemotional one. The emotional version displayed the full range of emotional expressions, whilst the unemotional one displayed a neutral face and voice at all times. Total 45 people participated in the study. In the result, no significant difference in fruit and vegetable consumption gains between the two agents and in the feedback people preferred emotional agent as compared to unemotional agent [12].Also,

participants provide their feedback that a lack of ‘negative’ emotions reduced the credibility of agents.



Figure 5: Facial expressions (clockwise from top-left: happy, warm, neutral, concern) [12]

In research work of [12] author claim that it was the first longitudinal study to examine the impact of an embodied agent’s emotional expressions on user perceptions and behaviour. However, it still lacks in providing emotional intelligence to embodied agents, which would enable them to interact effectively with users, for short and long-term interactions.

3.6 Different approaches of Emotion Modeling

We have performed an extensive review of different emotion modeling approaches and how they have been previously implemented in the field of artificial intelligence.

- Emotion animation approach with POMDP and COCOM
- Fuzzy-Based Approach for Emotion modeling

3.6.1 Emotion animation approach with POMDP and COCOM

Our research group proposed an emotion modeling technique [56] with the combination of OCC and COCOM to integrate emotions in embodied conversational agent. A new embodied conversational agent with ontology knowledge –base has been developed. The four contextual control modes have been used for decision making. The main focus of the [56] work was to generate emotions based on the situational information calculating the current emotional state of the agent which is backed up by the OCC model for emotions.

Online bookstore domain has been used for this embodied agent. In addition to advantages of POMDP-based dialogue management, the modified approach becomes possible to select actions dynamically according to different control modes, to handle uncertainty caused by errors like user’s lack of knowledge in a particular domain, and to engage embodied agents in lively interaction with software clients. In other words, emotion animation with POMDP and COCOM by including system response time and how the final emotion is chosen from the different contextual switching of the modes has been described in this work.

The four contextual control modes are mapped with 8 emotions and cannot represent many suitable facial expressions by their proposed model and also scaling of emotions were not provided by their system which is the limitation of the system and that can be improved by integrating new techniques and better emotion prediction can be done. We got motivation from this system to propose our own method which can improve embodied agents capability of more accurate user intention discovery and decision-making with more effective facial expressions [56].

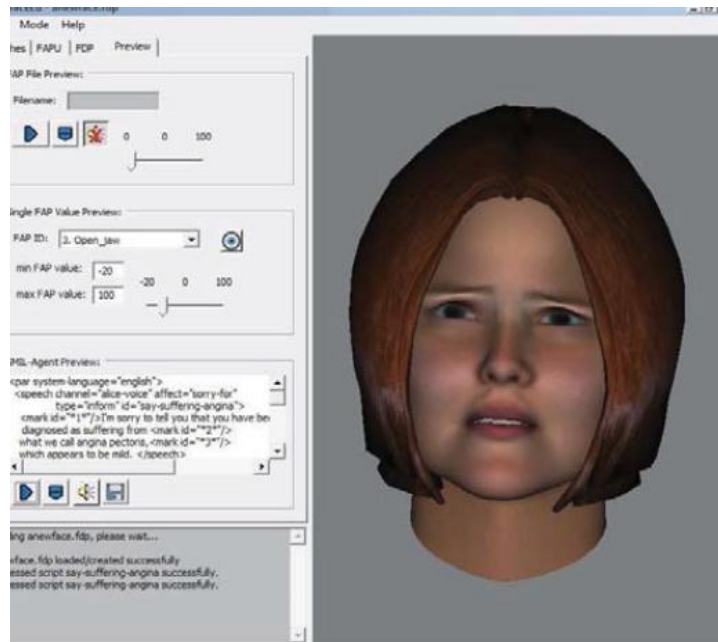


Figure 6: 3D animated face [56]

3.6.2 Fuzzy Based Approach for Emotional Facial Expression Modeling

Researchers in areas such as cognitive science, philosophy, and artificial intelligence have proposed various types of models of emotions based on different computational approaches such as fuzzy logic. Algorithms like Fuzzy Logic, Neural Networks, and Hidden Markov Model (HMM) are available. These algorithms makes sense as a solution but when it comes to quick run-time, Fuzzy is best suitable to predict accurate fuzzy information values [21][36].

As human's emotion decision includes fuzzy information, it is related to virtual human's inner variables and outer stimuli. Research on emotion model is still a meaningful subject in many fields [36]. Later, Fuzzy logic was used by researchers to use in emotion implementation work. Basically, fuzzy logic addresses concepts that do not have well-defined sharp boundaries; Zadeh in 1965 developed a fuzzy set theory that generalizes a classical set theory to allow the notion of partial

membership. The degree an object belongs to a fuzzy set, which is a real number between 0 and 1, is called the membership value in the set. The meaning of a fuzzy set is thus characterized by a membership function that maps elements of a universe of discourse to their corresponding membership values.

El-Nasr et al's [5] FLAME (Fuzzy Logic Adaptive Model of Emotions) model is a computational implementation of emotions which uses fuzzy logic rules to map assessments of the impact of events on goals into emotional intensities. FLAME consists of three components: an emotional component, a learning component, and a decision-making component. FLAME uses fuzzy sets to represent emotions, and fuzzy rules to represent mappings from events to emotions. For example, the model is capable of handling goals of intermediate importance, and the partial impact of various events on multiple goals. Moreover, the model is able to manage conflicts in mixtures of emotions. These kinds of problems can be addressed using other approaches as well, such as functional or interval-based mappings but fuzzy logic as formalism has been used mainly due the simplicity and the ease of understanding linguistic rules. FLAME could also be used as a computational model of emotions to enhance a variety of different computer interfaces or interactive applications. For instance, FLAME can be used to implement a believable embodied agent in animated character application such as interactive theatre productions or role-playing video games [5].

In order to incorporate emotion into the decision-making process, FLAME uses the fuzzy rule-based system to determine the behaviour according to the situation, the emotion, and mood of the agent. The limitations of this system are that the events and the agent's goals in FLAME have to be hard coded in the rules. Every time the domain is extended or changed, the rules have to be changed and verified.

Therefore, this makes FLAME a domain-dependent and inflexible approach. Moreover, FLAME does not provide a way of calculating the impact of an event on an agent's goal. Instead, it uses a predefined reward value for the user's action's impact on an agent's goal. Moreover, FLAME does provide some interesting work in the concept of emotion scaling as well. The testing with FLAME was performed through user assessment, based upon a questionnaire filled out by 21 volunteers who interacted with the system. FLAME is more concerned about the emotion filtering and intelligence of the agent which could be used to make the system intelligent up to some limit but it is not providing the technique to generate the facial expressions or emotion modeling by using its data as input [32].

The Parlevink research group [11] at the University of Twente worked with natural language interactions between humans and embodied conversational agents in virtual environments. They worked to build believable agents for several application areas: information, transaction, education, tutoring, and e-commerce. Authors state that for an embodied agent to be believable it is necessary to pay attention to both its capacities for natural language interaction and to non-verbal aspects of expression [11].

In [11] author proposed a fuzzy rule-based system to map representations of the emotional state of an animated agent onto muscle contraction values for the appropriate facial expressions. So the implementation was mainly focused on continuous changes in the intensity of emotions in order to display smoothly on the graphical face. The fuzzy rule-based system was used to implement patterns described by researchers dealing with facial expressions of humans, including rules for displaying the blends of expressions. Thus, the fuzzy rule-based system described in [11] generates lifelike facial expressions on a 3D face of an agent based on a

representation of its emotional state. Two aspects of facial expression modeling that researchers take into account are the continuous changes in expressions of an emotion depending on its intensity and to find a way to specify combinations or blends of expressions.

The emotional state vector (ESV) represents the emotional state of the agent, the author in [11] states that the human face cannot display all the combinations of emotion intensities that can be felt at the same time universally and unambiguously and only two emotions can be displayed clearly at the same time on the face because the face has only a limited number of regions to display emotions. A fuzzy set used for emotion intensity contains 5 elements: Very Low, Low, Medium, High, and Very High. Target was to improve the quality of the facial expressions by the smooth relationship function between emotion intensities and muscles' contraction levels. This smooth relationship function is obtained with fairly simple fuzzy if-then rules rather than with complicated formulas or intensively trained Neural Networks.

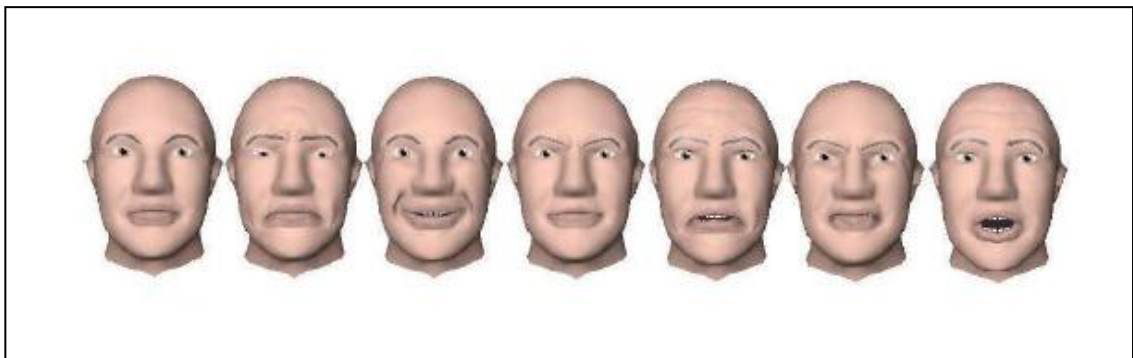


Figure 7: Basic emotions: Neutral, Sadness, Happiness, Anger, Fear, Disgust, and Surprise(From left to right) [10]

In [10] author claims that the fuzzy logic approach is more effective than other approaches. For the system [10] evaluation, researchers designed questionnaires to assess the recognisability of the expressions generated by the system. Basically,

Ekman's approach was followed to compute the facial expressions that arise from a blend of emotions. Their model applies a set of fuzzy rules to compute the mix of expressions of the six basic emotions. The face is divided into two parts: the upper and lower parts. The fuzzy rules explain which specific emotion is displayed on the upper part of the face and which one on the lower part. The muscular intensity is computed by fuzzy inferences as a function of the intensity of each emotion. The effect of the fuzzy membership function in the manner of expression is one of the issues that have not been discussed in their research group.

In order to create a robot with simulated emotions in [21] researchers propose a new robot named Shiau_Lu, which was developed based on the basic six emotions proposed by Ekman, these emotions are computed and controlled by a fuzzy controller based on fuzzy theory. It was basically a mobile based system with an Android operating system. Every time a robot gets input, its six emotional variables are used to represent the strength of its changing emotions [21]. The structure of the proposed approach is shown in Figure 8.

In [21] researchers added six emotions into that system: happiness, angry, fear, sadness, disgust, and surprise. There are four process stages in the system. In the first stage, a sentence is an input to the Emotional Change unit to change the emotional variables. The changed emotional variables are not only fed back as one of the new emotional inputs, but also sent to the second stage to perform fuzzification. In the third stage, the fuzzy inference mechanism uses fuzzy rules to find the primary emotion.

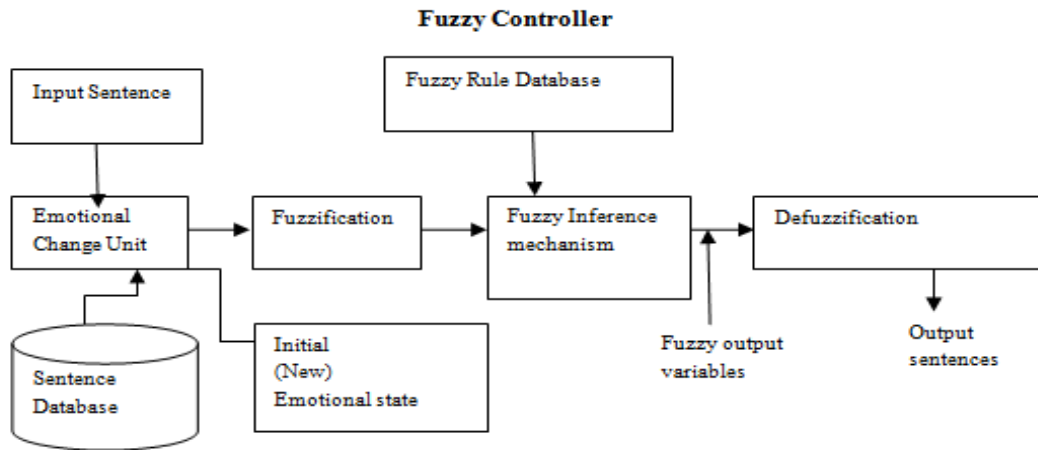


Figure 8: Structure of the fuzzy-based system [21]

In the last stage, defuzzification is performed by searching a sub-database of primary emotion and an adequate sentence is chosen as output. The six emotional variables are processed by Fuzzification in order to associate themselves with linguistic control rules. Because positive and negative emotions are mutually exclusive, the trapezoidal Membership Function is used as shown in figure 9.

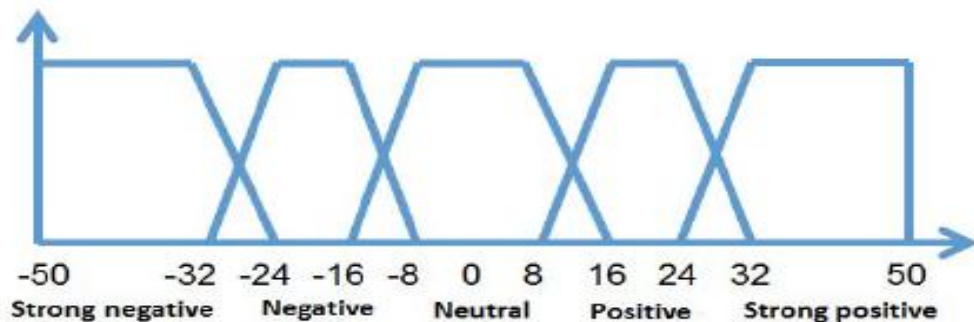


Figure 9: Trapezoidal Membership Function of fuzzy sets [21]

According to the values of Figure 9, the value of the Trapezoidal Membership Function ranges between -50 and 50. For every emotion, there are five fuzzy sets: strong negative, negative, neutral, positive, and strong positive. For example, according to [21] if any variable has less than -32, it is judged as strong fear; if its

value is from -32 to -24, it is judged by a random function as either strong fear or fear. The value ranging between -24 to -16 is judged as fear, and so on [21].

The Fuzzy Rule Base consists of the operation principles of the entire system, which are primarily defined based on human experience and various possible pre-conceived states, researchers in [21] use the following rules to select the primary emotion:

- Rule 1: If only one emotion is strong, then select the one.
- Rule 2: If more than one emotion is strong, then randomly select one of them.
- Rule 3: When no emotion is strong, then randomly select one that is not neutral.
- Rule 4: If all six emotional variables are neutral, then randomly select one of them.

A total of 25 data lists were in used to simulate different levels of intensity of different emotions; therefore, the same sentence can get different answers due to the current states of emotion. However, humans are unique and complicated, so there is a need to build a more intelligent system that can provide appropriate facial expressions and can respond in a more natural way [21].

3.7 Summary of Literature review

In this chapter, we discussed briefly the theories of emotions and specifically, models of emotions which has been developed and used by other researchers to solve the complex task of modelling emotions and to enhance the user experience. The importance and impact of emotional facial expressions on users decision-making process are discussed in this chapter which is evident by previous research work.

This chapter also discusses the different approaches for facial expression generation, limitations of those techniques and need to develop a new approach of emotional facial expression generation. From the literature, it is evident that the issues and limitations this HCI research area is still remaining unsolved or need improvement and each approach have its own drawback to be taken care of in future.

CHAPTER 4

Proposed Fuzzy Based Approach for Emotional Facial Expression Generation

4.1 Overview

This chapter gives a detailed explanation about the proposed methodology as the solution and the contribution of this thesis. The specific details of the methodology are developed thoroughly. The Architecture of the proposed method and corresponding proposed fuzzy based algorithm is covered comprehensively in this section.

4.2 Proposed Method

In this thesis, the focus is mainly on developing an approach for emotional facial expression modelling to enhance the user experience in decision-making while interacting with an interactive ECA which has realistic facial expressions. By using fuzzy algorithm this approach is implemented and the scaling of emotions in an ECA is also done. We present 3D animated embodied conversational agent which can show emotional facial expressions while interacting with users. The six basic emotions (anger, disgust, fear, happiness, sadness, and surprise) are computed and controlled by a fuzzy controller system

Overall, we propose a fuzzy based system with 3D animated face embedded with emotional facial expressions, which is a combined system with the (modified system) which is the work done in our research group [39].

As Figure 10 shows we derived 2 input variables from the modified system using as an input in our fuzzy based approach to generate facial expressions of the modelled face.

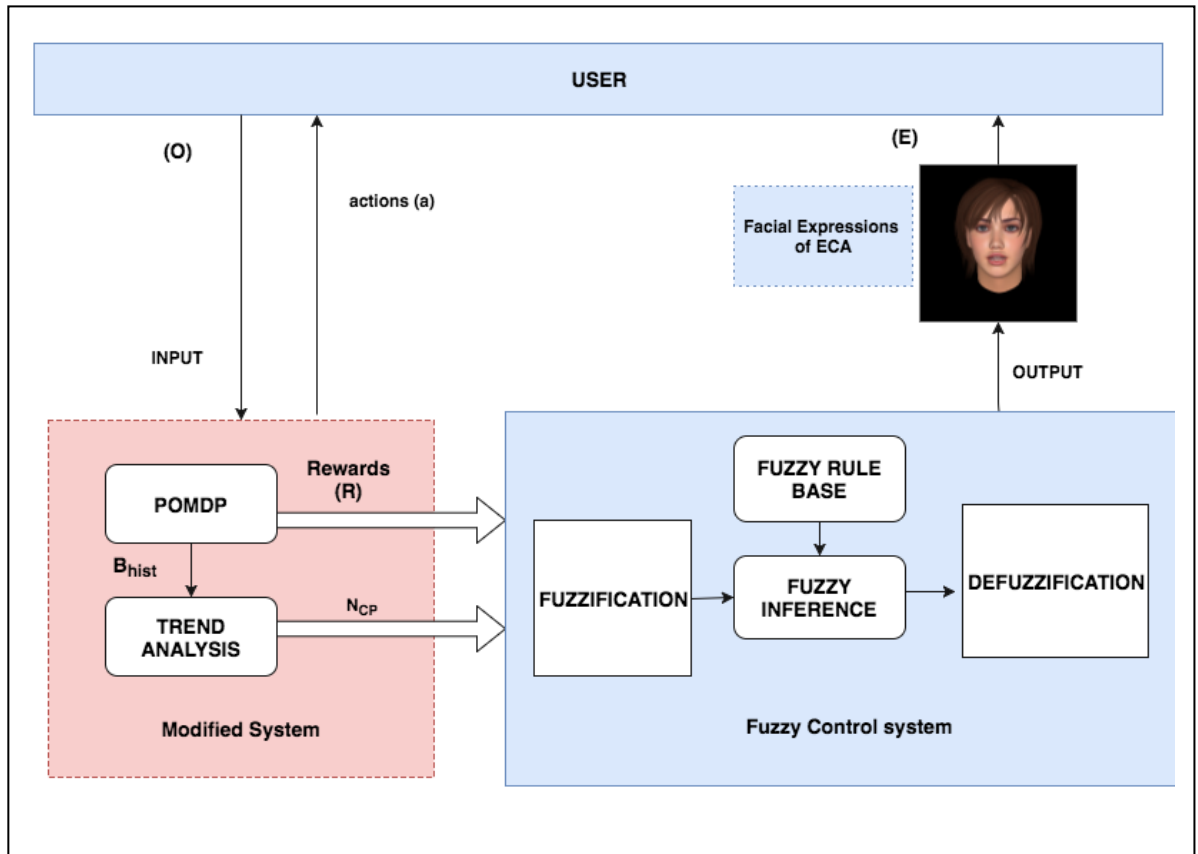


Figure 10: Architecture of proposed method

Algorithm of Proposed Method

First of all the main method is executed which takes the two inputs No. of change points(Ncp) and rewards(R), and it follows the four fuzzy controller system steps i.e. Fuzzification, Fuzzy rule base, Fuzzy inference, Defuzzification and gives final output in the form of facial expressions. Each algorithm step is explained one by one in details as follows:

Algorithm/Pseudo code of Proposed Method

```
1: METHOD: MAIN
2: MAIN
3:   Ncp ← {ST, T, O, SC}
4:   R ← {N, Z, P}
5:   F_Ncp ← FUZZIFICATION (Ncp)
6:   F_R ← FUZZIFICATION(R)
7:   FAMM ← LOAD_RULE_BASE ()
8:   W ← INFERENCE (F_Ncp, F_R, FAMM)
9:   output ← DEFUZZIFICATION (W, FAMM)
10:  GENERATE_FACIAL_EXPRESSION (output)
```

4.3 Definitions and Fuzzy logic steps

Fuzzy Sets (Input/output Variables): A Fuzzy Set is any set that allows its members to have different grades of membership (membership function) in the interval [0, 1]. As shown in Figure 10, there are two input variable sets, No. of change points (N_{CP}), and Rewards (R) that is used in proposed method as described below:

a.) No. of change points (N_{CP})

$$N_{CP} = \{ST, T, O, SC\}$$

Where, ST= strategic, T=tactical, O=opportunistic, SC= scrambled

The No. of change points comes from Trend analysis of the Belief State History (B hist), in other words, History of conversation (Information space), which has an impact on the generation of emotional facial expressions of an ECA.

For example : If person is going from 0 to t in the whole conversation, the transition from one state (s) to another (s'), and the actions (a) that are made in this duration by the system, creates history of belief state, so this history of conversation will be having impact on facial expressions.

b.) Rewards (R)

$$R = \{N, Z, P\}$$

where, N=negative, Z=zero, P=positive

The agent takes actions, and as a result receives observations and rewards. The Reward points are the value of appreciation to the system on the current decision of system. It could be any positive, zero, or negative value. The agent then has to find a way of choosing actions, which maximizes the total reward received over time.

For example:

If the user is giving observation (o) of happy then rewards will be some positive values.

If the system is moving from state (s) to (s') and the user is not satisfied then rewards could be zero or negative based on immediate action.

As shown in Figure 10 of the proposed method, the fuzzy system consists of four components which are Fuzzification, Fuzzy rule base, Fuzzy inference, and Defuzzification. Observation (O) is the input which modified system is receiving from the user and (E) is the final output that fuzzy system is providing to the user. Here we are adding an ECA and Implementing fuzzy based approach in the overall system. The whole fuzzy based proposed method is described step by step thoroughly in the next section.

Step 1. Fuzzification and Membership function

Fuzzification is the first step which involves two processes: derive the membership functions (MFs) as defined in *chapter 2 Section (2.5)*, for input and output variables and represent them with linguistic variables. There are different forms of membership functions [3] such as triangular, trapezoidal, piecewise linear, Gaussian, or singleton. In this proposed method, two types of Membership functions (MFs), Triangular and Trapezoidal are used. Due to their simple formulas and computational efficiency, both triangular MFs and trapezoidal MFs have been used extensively, especially in real-time application implementations.

Step 1: Algorithm(Fuzzification)

```

1: METHOD: FUZZIFICATION
2: INPUT: x, segment
3: OUTPUT: F_segment
4: FUZZIFICATION
5:   F_Ncp ← EMPTY LIST
6:   F_R ← EMPTY LIST
7:   FOR i in segment
8:     F ← TRAPEZOIDAL_MF(x, LOAD_RANGE(i))
9:     Add F to F_Ncp
10:  ENDFOR
11:  return F_segment
12: METHOD: TRAPEZOIDAL_MF
13: INPUT: x, a, b, c, d
14: OUTPUT: F
15: TRAPEZOIDAL_MF
16:   return MAX(MIN((x-a)/(b-a), 1, (d-x)/(d-c)), 0)
17: METHOD: TRIANGULAR_MF

```

```

18: INPUT: x, a, b, c
19: OUTPUT: F
20: TRIANGULAR_MF
21: return MAX(MIN((x-a)/(b-a), (x-b)/(c-b)), 0)

```

Trapezoidal membership function: A trapezoidal MF is specified by four parameters {a, b, c, d} as follows:

$$\text{Trapezoidal MFs } (x; a, b, c, d) = \max \left(\min \left(\frac{x-a}{b-a}, 1, \frac{d-x}{d-c} \right), 0 \right)$$

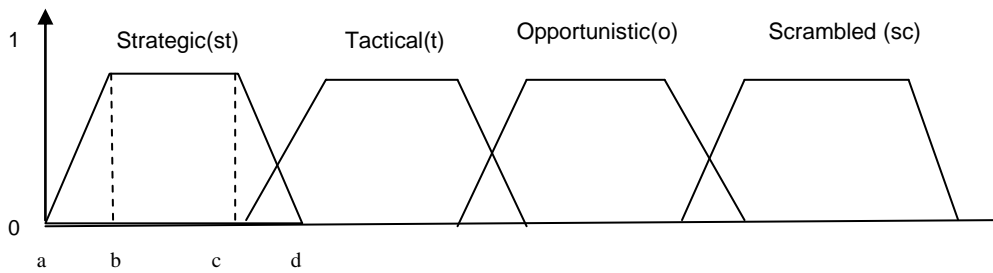


Figure 11: Trapezoidal membership function for No. of change points (NCP)

$F_N(R), F_Z(R)$, membership function values calculated for Rewards (R) and $F_{ST}(N_{CP})$, $F_T(N_{CP})$, $F_O(N_{CP})$, $F_{SC}(N_{CP})$ four membership function values calculated for each component of set of N_{CP} . Let's assume $x=6$, $a=3, b=4, c=7, d=8$ and calculation for $F_{ST}(N_{CP})$ by using the given Trapezoidal Membership function formula will be

$$\begin{aligned}
\text{Trapezoidal MFs } (6; 3, 4, 7, 8) &= \max \left(\min \left(\frac{6-3}{4-3}, 1, \frac{8-6}{8-7} \right), 0 \right) \\
&= \max \left(\min(3, 1, 2), 0 \right) \\
&= \max(1, 0)
\end{aligned}$$

Similarly, for the second input variable Rewards (R), three membership functions $F_N(R)$, $F_Z(R)$, $F_P(R)$ can be calculated by using Trapezoidal membership function.

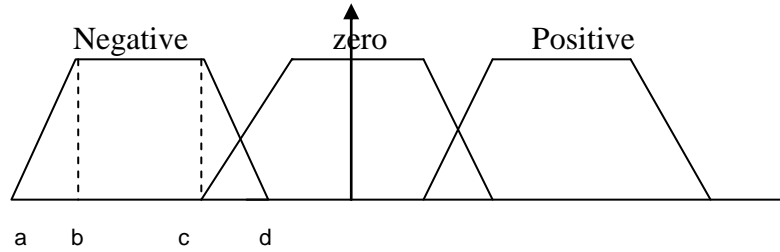


Figure 12: Trapezoidal membership functions for fuzzy set of Rewards (R)

Triangular Membership Functions: A Triangular MF is specified by three parameters $\{a, b, c\}$ as follows :

$$\text{Triangular}(x; a, b, c) = \max\left(\min\left(\frac{x-a}{b-a}, \frac{c-x}{c-b}\right), 0\right)$$

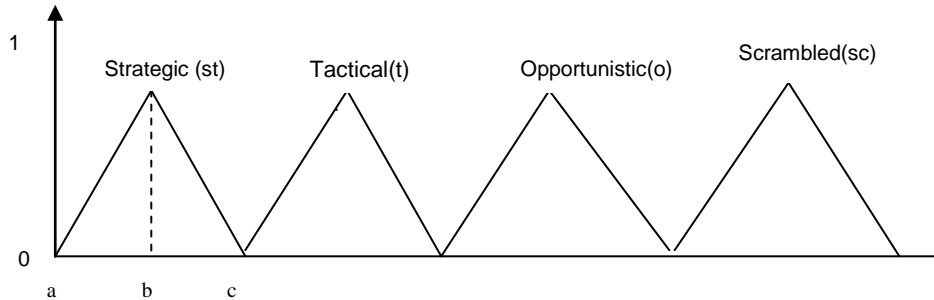


Figure 13: Triangular membership function for No. of change points (N_{CP})

By using Triangular MFs, $F_{ST}(N_{CP})$, $F_T(N_{CP})$, $F_O(N_{CP})$, $F_{SC}(N_{CP})$ four membership function can be calculated for each component of set of N_{CP} .

Similarly, for the second input variable Rewards (R), three membership functions $F_N(R)$, $F_Z(R)$, $F_P(R)$ can be calculated by using Triangular membership functions.

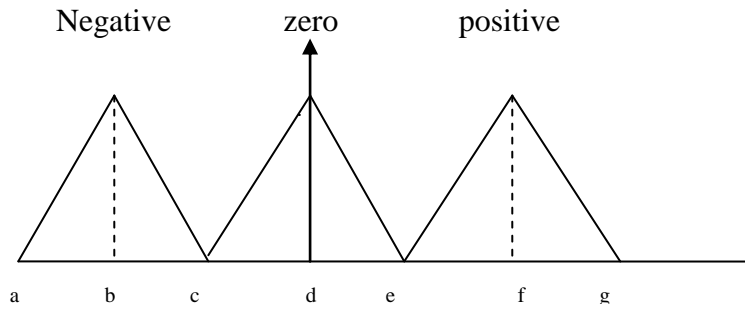


Figure 14: Triangular membership functions for fuzzy set of Rewards (R)

Step 2: Fuzzy Rule base

The fuzzy Rule Base consists of the operation principles for the whole system, which are defined based on human experience. In real applications, it is very hard to derive a certain relationship between the input and the output, or the relationship between those inputs and outputs are very complicated even when that relationship is developed. Fuzzy mapping rules are a good solution for those situations. This thesis making an assumption for the 6 basic emotions {anger, happiness, surprise, disgust, and sadness, fear} to put that data into a table for mapping based on human experience.

FAMM	Strategic	Tactical	Opportunistic	Scrambled
Negative	Disgust	Anger	Anger	Fear
Zero	Fear	Sad	Surprise	Sad
Positive	Happy	Happy	Surprise	Surprise

Table 4: Fuzzy Rules matrix of proposed method

As shown in table 4, a fuzzy associative memory matrix (FAMM) expresses fuzzy logic rules in tabular form. The rows and columns are representing two inputs,

the No. of change points(N_{CP}), and rewards(R), and these inputs are related to IF parts in IF-THEN fuzzy rules. The conclusion or output which is the emotion, in this case, can be considered as a third-dimensional variable that is located at the cross point of each row (R) and each column(N_{CP}), and that conclusion is associated with the THEN part in IF-THEN rules.

For example:

IF Rewards (R) IS Negative AND (N_{CP}) IS scrambled THEN output will be FEAR

IF Rewards (R) IS Positive AND (N_{CP}) IS strategic THEN output will be HAPPY.

All mapping rules follow a similar strategy, which is very similar to a human being's intuition.

Step 3. Fuzzy Inference

After evaluating the result of each rule, these results should be combined to obtain a final result. This process is called inference. Fuzzy set operations are used in this process.

Step 3: Algorithm (Fuzzy Inference)

```
1: METHOD: INFERENCE
2: INPUT: F_Ncp, F_R, FAMM
3: OUTPUT: W
4: INFERENCE
5: FOR i in F_Ncp.LENGTH * F_R.LENGTH
6:      $W[i] \leftarrow F\_Ncp[i] + F\_R[i] - F\_Ncp[i] * F\_R[i]$ 
7: return W
```

Fuzzy set operations: The evaluation of the fuzzy rules and the combination of the results of the individual rules are performed using fuzzy set operations.

FAMM	Strategic	Tactical	Opportunistic	Scrambled
Negative	W1=?	W4=?	W7=?	W10=?
Zero	W2=?	W5=?	W8=?	W11=?
Positive	W3=?	W6=?	W9=?	W12=?

Table 5: Fuzzy Rules matrix values

Fuzzy set operation can be performed by using “OR” and “AND” operations as given below:

$$w_i (F_{[N,Z,P]}(R), \text{OR } F_{[ST,T,O,SC]}(N_{CP})) = F_{[N,Z,P]}(R) + F_{[ST,T,O,SC]}(N_{CP}) - (F_{[N,Z,P]}(R) * F_{[ST,T,O,SC]}(N_{CP}))$$

$$w_i (F_{[N,Z,P]}(R), \text{AND } F_{[ST,T,O,SC]}(N_{CP})) = F_{[N,Z,P]}(R) * F_{[ST,T,O,SC]}(N_{CP})$$

where, (N_{CP}) and (R) are two independent variables.

For example: With “OR” set operation value of W1 can be calculated as given below:

$$w1 (F_{ST}(N_{CP}) \text{OR } F_N(R)) = F_{ST}(N_{CP}) + F_N(R) - ((F_{ST}(N_{CP}) * (F_N(R)))$$

With “AND” set operation value of W1 can be calculated as given below:

$$w1 (F_{ST}(N_{CP}) \text{AND } F_N(R)) = ((F_{ST}(N_{CP}) * (F_N(R)))$$

Let’s assume value of $F_{ST}(N_{CP}) = 0.2$ and $F_N(R) = 0.3$ calculated by any one

(Triangular or Trapezoidal) membership function and we can calculate w1 as follows:

$$w1 (F_{ST}(N_{CP}) \text{AND } F_N(R)) = (0.2 * 0.3)$$

$$w1 (F_{ST}(N_{CP}) \text{ AND } F_N(R)) = (0.6)$$

Similarly, by using these set operations, values of w_i which contains all the output variables $w_1, w_2, w_3, w_4, w_5, w_6, w_7, w_8, w_9, w_{10}, w_{11}, w_{12}$ is calculated.

Step 4. Defuzzification

This is the final step of fuzzy system controller. As after the fuzzy inference step, the fuzzy conclusion or output is still a linguistic variable or a fuzzy value, and this linguistic variable or result is converted to the crisp variable or crisp output via the defuzzification process. First, the consequent membership function $FAMM_i$ can be converted into a crisp then the COG (center of gravity) method is applied to the rules with crisp consequents, this can be expressed as

$$x = \frac{\sum_i w_i \cdot FAMM_i}{\sum_i w_i}$$

Where, w_i is the degree to which the i th rule matches the input data.

Step 4: Algorithm (Defuzzification and final output)

- 1:METHOD: DEFUZZIFICATION
- 2:INPUT: W, FAMM
- 3:OUTPUT: coefficient of facial expressions
- 4:DEFUZZIFICATION
- 5: Sum_W \leftarrow 0
- 6: Sum_E \leftarrow 0
- 7: FOR i in W
- 8: Sum_W = Sum_W + W[i]
- 9: Sum_E = Sum_E + FAMM[i]
- 10: return Sum_E/Sum_W

11:METHOD: GENERATE_FACIAL_EXPRESSION

12:INPUT: Coefficients of facial expressions

13:GENERATE_FACIAL_EXPRESSION

14: // Create a 3D Face with given coefficient of facial expressions

15: // Animate the Expression

For Example:

$$X = \frac{w1.\text{disgust} + w2.\text{Fear} + w3.\text{happy} + w4.\text{anger} + w5.\text{sad} + w6.\text{happy} + w7.\text{anger} + w8.\text{surprise} + w9.\text{surprise} + w10.\text{fear} + w11.\text{sad} + w12.\text{happy}}{w1 + w2 + w3 + w4 + w5 + w6 + w7 + w8 + w9 + w10 + w11 + w12}$$

$$X = \frac{w1 \times \text{disgust} + [w2 + w10]\text{Fear} + [w3 + w6 + w12]\text{happy} + [w4 + w7]\text{anger} + [w5 + w11]\text{sad} + [w8 + w9]\text{surprise}}{w1 + w2 + w3 + w4 + w5 + w6 + w7 + w8 + w9 + w10 + w11 + w12}$$

$$X = \frac{0.0\text{disgust} + 0.1\text{Fear} + 0.6\text{happy} + 0.0\text{anger} + 0.1\text{sad} + 0.2\text{surprise}}{1}$$

This step will provide the final output that is the name of emotion and scaling of emotion which appear on the face of an ECA.

CHAPTER 5

Implementation and Usability Study

5.1 Overview

This chapter illustrates the experimental work done in this thesis based on the proposed system. The experimental analysis has been subdivided into two sections. The beginning of this chapter will discuss the Face modeling [39] and simulation of facial expressions which we added in the ECA. It also describes fuzzy implementation for facial expression generation. The second section is about the usability study, the proposed method for usability study that has been conducted as a part of this thesis to test the system performance after adding the facial expressions to ECA and impact on user's decision-making process by testing the system by real users.

5.2 Implementation

5.2.1 Face Modelling and Expressions

FaceGen Modeller 3.0 is used for modeling the 3d face expressions. By following below steps we can achieve 3D Face Model and expressions [24].

- From Create Tab, we can upload an image and mark the feature points on the image which we have uploaded as illustrated in the help section.
- FaceGen Modeller will analyze the photo uploaded and marked feature points to create 3D Face.
- From Model Sets Tab, we can add the Hair, images for eyes etcetera.
- From Expressions Tab, we can obtain the required expression by increasing and decreasing the value in the slider.
- Finally, we can export the Modelled face into .obj, .wrl etcetera.

In the experiment part of this thesis we use .obj which consists of the vertices, vertex normal, vertex texture and, faces defined along with the linkage to material file (.mtl). Every material file consists of the assets we used in a display the texture like images. In the experiment part of this thesis we use .obj which consists of the vertices, vertex normal, vertex texture and faces defined along with the linkage to material file (.mtl). Every material file consists of the assets we used in display the texture like images.

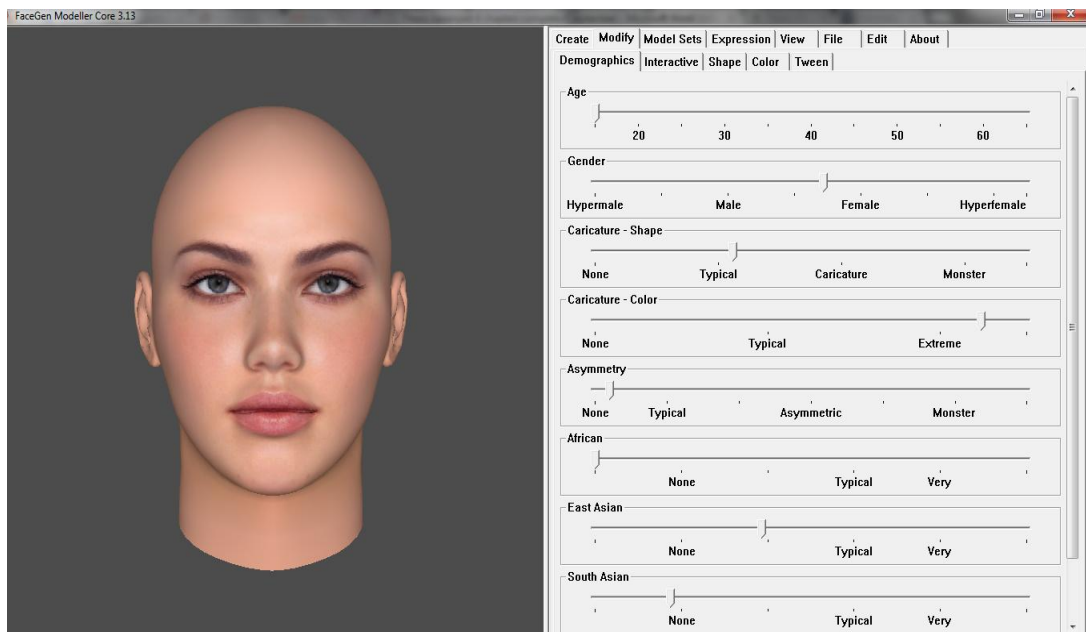


Figure 15: Modelled face in facegen modeller [39]

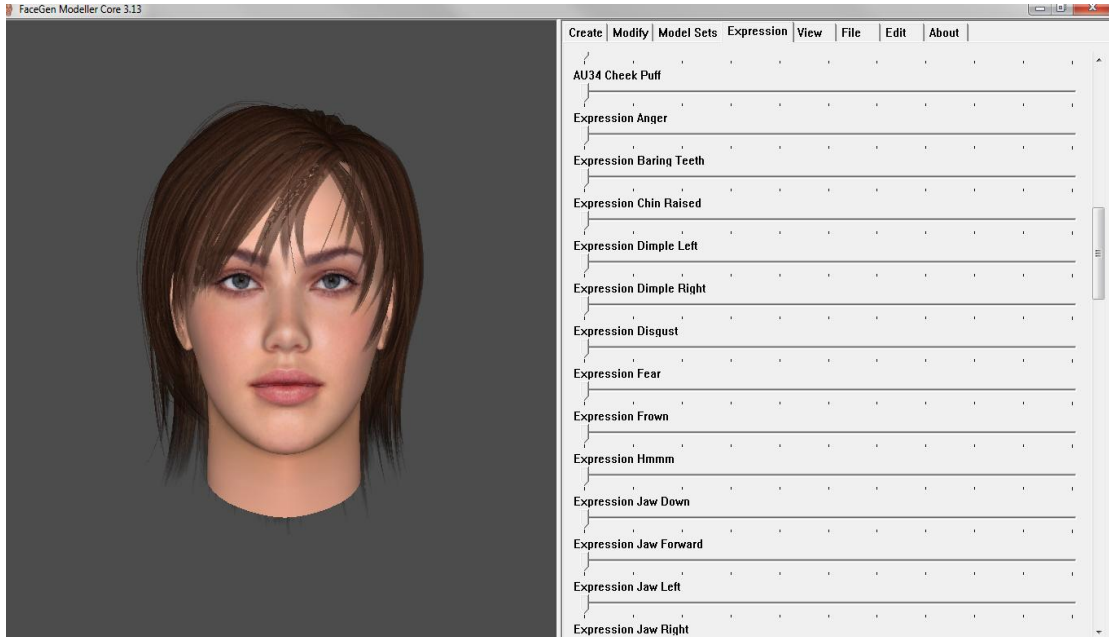


Figure 16: FaceGen Modeller for expressions simulation

Various emotional facial expressions can be created with FaceGen Modeller as we modelled basic 6 emotions from it in an ECA as shown in Figure 16.

The combination of 6 emotions has been modelled in which total 63 combinations were made by calculating the factorial of each emotion. It could be the combination of 2, 3, 4, 5, or 6 mixed emotions. For example if H=Happiness, A=Anger, F=Fear, SA=Sad, SU=Surprise, and D=Disgust then combination of 2 emotions can be denoted as {H,SU}. Combination of 3 emotions {H,A,F}, Combination of four emotions {A,F,D,SA}, Combination of 5 emotions could be {D,SU,S,F,A} respectively. Similarly, total 63 combinations have been developed and loaded in the system.

For instance, six basic emotional facial expressions added to ECA are given below:



All the other 63 new combinations of each emotion with other emotions were used for experiment work with fuzzy implementation.

5.3 Fuzzy implementation

In this thesis, Fuzzy implementation is done by Java 7.0 on Windows 7 operating system. For coding and debugging Eclipse IDE (3.6) is being used. The GUI of Modified System, developed by Vijay Mulpuri in his thesis work [39] was used for experimental work by adding an ECA with facial expressions to the system which has online bookstore domain. The simulation of fuzzy was done by the code of java 7.0.

In the Existing Modified system, a Fuzzy system has been implemented with the four (fuzzification, fuzzy rules, fuzzy inference, defuzzification) steps of proposed method given in chapter 4, section 4.2, by adding an ECA with emotional facial expressions.

In the interface of the modified system, an ECA has been added or loaded with all the 63 combinations of emotional facial expressions. The three.js library was used to load the ECA into the system with all the modeled emotions. Fuzzy simulation has been done before the actions made and also, after getting the results from Trend analysis of the existing system. According to the fuzzy input variable values, a combination of emotions will be loaded from the 63 combination files which show the final output of emotional facial expressions on the 3D face.

The screenshot shows an IDE with the following components:

- Projects Panel:** Shows a project structure with folders like 'LogWeb Pages', 'META-INF', 'WEB-INF', and 'com.vijay'.
- Source Editor:** Displays the code for `Fuzzy.java`. The code includes:


```

83
84
85
86 double newBelief = StateEstimator.process(input);
87 BeliefHistory historyInstance = BeliefHistory.getInstance();
88 historyInstance.addHistory(newBelief);
89
90 int ncp = TrendAnalysis.process(historyInstance.getHistory());
91 String k = KnowledgeLevelSelector.process(ncp);
92 Policy policy = PolicySelector.process(k, newBelief);
93
94 String[] expressions = {"A", "D", "F", "H", "SA", "SU"};
95 double[] expressionCoeff = Fuzzy.process(ncp, policy.getReward());
96 String expModel = "";
97 for(int i=0; i<expressions.length; i++){
98     if(expressionCoeff[i]>0.0){
99         expModel += expressions[i]+"-";
100     }
101 }
102 expModel = "H_SU"; expModel.substring(0, expModel.length()-1);
103
104 return "{action:'"+policy.getAction()+"', 'expression':'"+expModel+"'}";
105

```
- Output Console:** Shows the Apache Tomcat 8.0.27.0 log with the following output:


```

(Leng th, Current, Old): (4,0.27649330097300,0.27649330097300)
(Leng th, Current, Old): (4,0.2229938427975151,0.2229938427975151)
(Leng th, Current, Old): (4,0.5,0.5)
New Belief: 1.0
{action:'Can you repeat your requirement again?', expression:'H_SU'}
17 -> 0.19675926146683853
18 -> 0.278549396697386
19 -> 0.2229938427975151
20 -> 0.5
(Leng th, Current, Old): (4,0.19675926146683853,0.19675926146683853)

```

Fuzzy.java file code added into the app.java

In the line 92 of `app.java` file, an array of expressions has been created which contains {A,D,F,H,SA,SU} expression notations, and in the line 93 the co-efficient of expressions were calculated by the fuzzy input values *Ncp* and *reward points*

through *fuzzy.java* file simulation code given in Appendix C. From the co-efficient an expression model is created and passed to the front-end to load the expression model as shown in screenshot.

Interface

In the interface of proposed ECA system, it has one text box for users to type their answers and one log window near the ECA which contains the log of conversation or dialogs. The list of services is provided to users on the interface from which they can select the services for the software according to requirement. The Interface used in experimental work is shown in Figure 17.

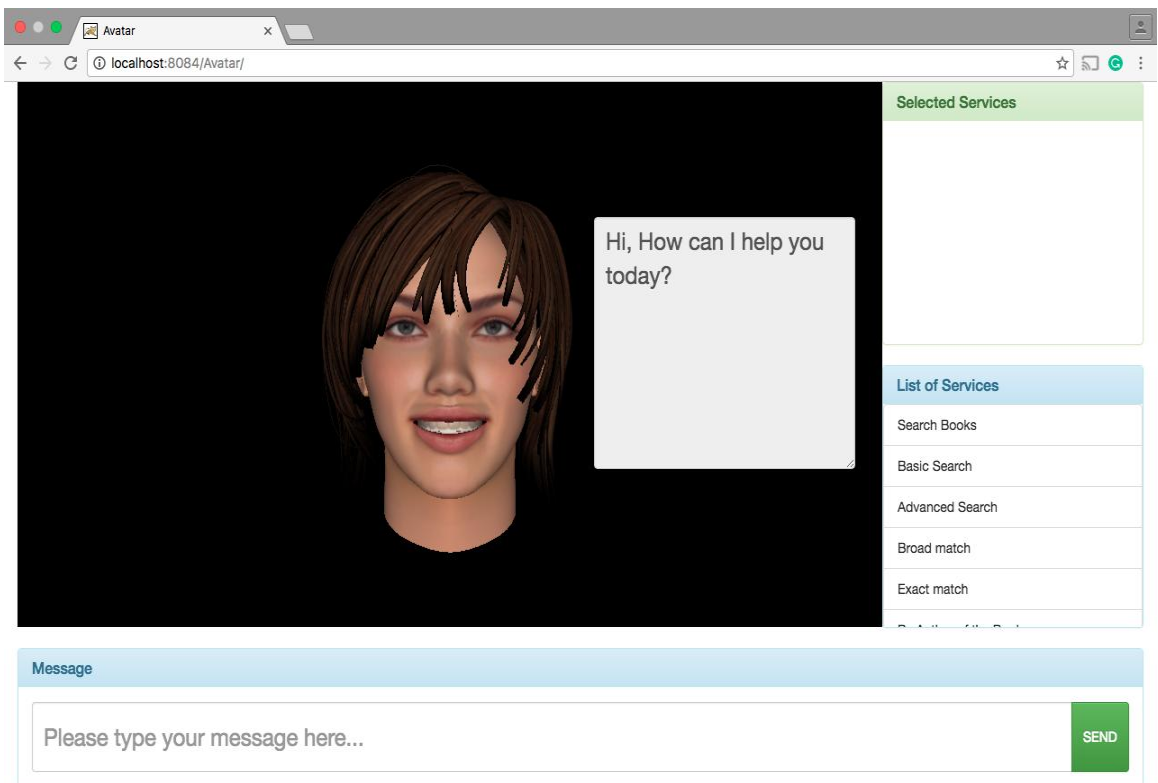


Figure: 17 Graphical user interface with a proposed ECA

Users are allowed to choose any number of services from the list and list of provided services is: “locate a book”, “Get reference to a book”, “Get a list of relevant books”, “Pick a book from the list”, “Search relevant books”, “Sort books in a list”, “Search in book keywords”, “Advanced search”, “Get detailed info of a book”, “Get

publication info”, “Get contents”, “Broad match”, “Exact match”, “Manage a shopping cart”, “Add a book to a cart”, “Remove a book from cart”, “Get reference to a item in a shopping list”, “Get a shopping list”, “Pick an item in shopping list”, “place an order”, “Get summary of an order”, “Calculate the total price”, “Set delivery information”, “Set payment information”, “Confirm an order”.

5.4 Usability Study

The usefulness of User interfaces with Embodied agents has increased greatly in recent years. Measuring usability of those interfaces is an essential task to ensure the application is accurate and safe for users. A usability study is the testing technique in HCI (Human Computer Interaction). It is one of the most important aspects of software quality; several methods have been introduced in order to establish techniques capable of evaluating this attribute from earliest phases of the software development process.

The purpose of usability Study is to find the problems and make recommendations to improve the utility of product during its design and development that are described in this section [20].

5.4.1 Definition: The ISO 9241-11 standard (ISO 9421-11, 1998) defines usability as

“Extent to which a product can be used by specified users to achieve specified goals with effectiveness, efficiency and satisfaction in a specified context of use”.

Usability in ISO Standard	Description
The ISO 9241-11 (1998)	Identify efficiency, effectiveness, and satisfaction as major attributes of usability.
ISO/IEC 9126-1 (2001)	Define the standard as a software quality attributes that can be decomposed into five different factors, including understandability, learnability, operability, attractiveness, and usability compliance.
ISO/IEC 9126-4 (2001)	Define the related concept of quality in use as a Kind of higher-order software quality attributes.
The ISO/IEC 14598-1 (1999)	A model for measuring quality in use from the perspective of internal software quality attributes

Table 6: ISO Standard related to measurement, [22]

Usability is becoming very important software criterion, but the present usability measurement methods are either difficult to apply or dependent upon evaluators' expertise [34] Usability testing is a dynamic process that can be used during the whole process of developing interactive multimedia software. To develop effective interactive multimedia software, dimensions of the usability testing were classified into the general categories of learnability, performance effectiveness, flexibility, error tolerance, and user satisfaction. In the process of usability testing, evaluation experts give proper attention towards the nature of users and tasks [33].

5.4.2 Dimensions of Usability Testing

The set of dimensions of usability testing is as shown in table 6.

Dimensions	Goals and objectives
Learnability	To evaluate the degree of user's ability to operate the system to some defined level of competence after some degree of training, and/or to evaluate the degree of the ability of infrequent users to relearn the system after periods of inactivity.
Performance Effectiveness	To quantitatively measure the ease of using the system, either by speed of performance or error rate.
Flexibility	To evaluate the degree to which the system enable a user to achieve his or her goal
Error Tolerance & System Integrity	To test error tolerance in using the system and/or system integrity for preventing data corruption and loss
User Satisfaction	To measure the user's perceptions, feelings, and opinions of the system

Table 7: Dimensions of usability study [33]

According to the research of [22] the authors state that measuring usability is an important task to make sure that the application is accurate, has sufficient speed ,

does not taking too much time, and will ensure the safety of users from strain injury as well. Software applications such as news alert, entertainment and, weather forecasting become more popular and this popularity of software applications have attracted researchers to extend the studies on the usability of applications.

Usability is about how the system interacts with the user. Usability engineering defines the final usability level and ensures that the software under usability testing reaches that level. The usability attributes can be measured by observing the users when they are working with the system or by having interviews and questionnaires after they used the system. The questions in interview and questionnaires should be related to the interaction between the user and the machine [40]. Gould and Lewis have proposed “Famous Rules” for usability engineering. These famous rules are as follows [40]:

- Early focus on the users
- User participation in the design of software or product
- Accurate Coordination of the different parts of the interface
- Empirical user testing and iterative revision of designs

In [42], Nine heuristics are proposed: simple and natural dialogue, speak the user’s language, minimize user memory load, consistency; provide feedback; provide clearly marked exits; provide short cuts; good error messages, and prevent errors. There is another method cognitive walkthroughs, which uses more explicit, detailed procedure and conducts a more work-based usability analysis by testing real users faced with the system. In order to analyze the quality of the interface in directing the user to accomplish a specific task, the following three simple questions are asked mainly [42]:

- Will the correct action be made sufficiently evident to users?

- Will users connect the correct action's description with what they are trying to achieve?
- Will users interpret the system's response to the chosen action correctly?

The answer to all these questions should be a "yes"; in case there is a "no" answer to any of these questions, problems may occur.

5.4.3 Usability evaluation methods

There are a variety of methods/techniques for usability testing available which can be use for different purposes and circumstances. Each method/technique for usability testing has its advantages and limitations as shown in table 7. .Empirical methods are more useful in software engineering. There are two general groups of methods for usability testing which are Empirical and Analytical as explained below [33].

a) Empirical Method: It's useful where human interacts with machines via Observation or survey conducted for real users. This method can be categorized into following types:

a) Field study b) Lab based c) Interviews d) Online survey

b) Analytical Method: This method provides early feedback about the design of the Interactive system to software testers. This method can be categorized into following types:

a) Cognitive Walkthrough b) Usability Inspection c) Heuristic Evaluation

Methods/Technique	Advantages	Limitations
Heuristic Evaluation Methods: To use a predefined list of heuristics to find usability problems	Inexpensive to implement. To identify problems early in the design process.	Debriefing session is necessary to find the indication of how to fix problems
Pluralistic Walkthroughs: To evaluate a product from the perspective of the end-user.	Easy to learn and use. To allow iterative testing. To meet the criteria of all parties involved in the test.	Difficult to find a proper context of task- performed for usability testing
Formal Usability Inspections: To test within the context of specific user profiles and defined goal-oriented scenarios.	To represent different knowledge domains. To get a list of problems and solutions for usability. To evaluate both cognitive processing and behavioural tasks	Generally, end-users are not involved. Difficult to find a proper testing context of task-performed.
Empirical Methods: An experimental test to prove or disprove a hypothesis	Effective for finding cause and effect. Effective for addressing a specific question or problem.	Time consuming and expensive to conduct. Need to train a skilled practitioner.
Cognitive Walkthroughs: To test the ease of learning to use product by exploration.	Effective for predicting problems. Effective for capturing cognitive process.	Need to train a skilled evaluator. Focused on one attribute of usability
Formal Design Analysis: To test the understanding of the task requirements to be performed	Adequate for analyzing a minimum of problem-solving behavior. Effective for identifying problems in the early stage.	Difficult to learn and use. Only suitable for analyzing expert behaviour

Table 8: Methods/Techniques of Usability Testing [33]

5.4.4 Usability Life Cycle

The usability engineering life cycle has three stages as follows [30]:

a) Predesign Stage

During the predesign stage of the usability engineering lifecycle, the emphasis is on the target user and the tasks that the end user will perform. In this stage, the focus should be on the user; the nature and needs of the users must be understood. There can be several different criteria which can provide us with useful information about the user. For example user's experience with similar systems can be a very important factor in most cases. Usability goals should be set during this stage. This stage contains mainly two steps: Early focus on user type and setting usability goals for the user [30].

b) Design Stage

In the design stage, the emphasis is on the proper implementation. The released system should be useable and useful for the user. Usually, a prototype is designed based on the usability principles and the needs of the users. This prototype is tested with the real users, and feedback from these users is used to analyze whether the design will meet required goals. This stage is very important and mainly focuses on three steps: User participation in the design, Coordination of the different parts of the interface and, Empirical user testing [51].

c) Post design Stage

The post design stage is the study of the product to be used in the field. The testing is conducted on the real system with the real users. In this stage, the design can be revised and retested for the future versions of the product [51].

5.4.5 Data Collection Methods for Usability Testing

According to the requirement of the work, by selecting the usability evaluation method different data collection methods can be used to analysis the data and find results [33] as given in below table 8:

Method	Explanation
Observation/interview	Data by observing the user's behaviour throughout the usability testing. Data collection by the user's verbal report using interview after completing the usability testing
Thinking-Aloud	Data collection using user's thoughts throughout the usability testing
Questionnaire	Data collection using question items that address information and attitude about the usability of the software
Video Analysis	Data collection by one or more videos used to capture data about user interactions during usability testing
Auto Data- Logging Program	Data collection by auto-logging programs used to track user actions throughout the usability testing.
Software Support	Data collection using a software designed to support the evaluation expert during the usability testing process and to provide an evaluation summary

Table 9: Data Collection Methods for Usability Testing [33]

A usability study was conducted to test the user preferences for effective task completion while interacting with a robotic conversational animated face. As computer interfaces using facial animation are being used more and more every day but very few researchers have studied the effect and the convenience of the use of an animated face in HCI, and in particular, in human-robot interaction [45]. Focused

usability factors were efficiency, effectiveness and interaction experience or user satisfaction that users may perceive while communicating with an animated face as a graphic conversational interface. In [45], the author used the questionnaire sample for evaluation to get the opinion about the animated face (Jessica) and found it positive. People mentioned that it is friendly and makes communication easier with facial expressions and can be used as a good support tool in any domain. But there were negative opinions too, like that the animated face was not good looking enough and caused user distractions. The questionnaire tool provided by [45] research group is used in this thesis to do the evolution of the proposed approach by adding few more questions. The results from [45] reveal that according to user preferences, the 3D face with emotions improves the understanding and the interaction of the system making it more realistic and friendly. But there are limitations in their study i.e less number of participants (22) which is less than expected to do data collection and all participants are from same field and level of study (masters) which could be taken from different fields and different level of studies such as under-graduate and graduates. They are also mentioning about the male and female number of participants in the study but the gender has no impact related to the performance of the system. So these limitations can be overcome by the usability study done in this thesis.

In [51] research work author compares two software systems, one text-based system, and another graphical interface. Both systems were subjected to usability evaluation by two groups of users with varying levels of software development expertise. The first group included 20 students with very little or no experience in software development skills from the business department. The second group consisted of 50 computer science students. A usability study was conducted to justify that the proposed design can positively improve the usability of the user interface. The

questions of the questionnaire were designed to address the main factors of usability, which are learnability (Easiness), efficiency, error rate, user satisfaction and necessity. But there should be equal number of participants in the study if comparing computer and non-computer science.

In [30] research work, for the purpose of the usability testing of the system, both the analytical as well as empirical testing was conducted. At different stages of the system development, evaluation methods like usability inspection and the cognitive walkthrough were used. Based on the collected results from both computer science and non-computer science students, the author concluded that his proposed interactive system improves the efficiency of the software customization process. They designed questionnaires to address the main factors of usability and live observation of participants has been done to collect the user-experience.

In [31] authors propose a modified usability study scale which is used in their research work of measuring the usability of mobile applications for phone and tablets. Several studies have been conducted that have established benchmarks for a large number of products and services, allowing researchers to compare their results with these benchmark results. Not only is the SUS (System usability scale) used in published work, but Sauro and Lewis in 2009 reported that it is widely used in unpublished work as well, noting that it was used in 43% of the unpublished studies in their sample. This suggests that it is a tool that is widely accepted by both academicians and practitioners which are described in [31].

Therefore, the proposed method of the usability study of this thesis is based on the investigation of previous studies that has been done by several researchers to evaluate their proposed systems. The questions of the online survey are designed exactly based on the existing questionnaire tools and also on previous research of

usability study in computer science field. We are overcoming the limitations of previous studies by taking more number of participants and also from different fields and level of study in this thesis.

5.5 Proposed Usability Testing Method

In this research, both analytical and empirical testing has been conducted. For analytical testing, a combination of usability inspection and cognitive walkthroughs methods has been used along with famous rules, as much as it was applicable and practicable with the available feasibilities, in different phases of designing the system.

The main purpose was to improve the usability of the system by enhancing the user-experience. To improve the usability of the only text-based and without emotions ECA system, the interactive ECA with facial expressions is added and emotional facial expression modeling is implemented. It is expected to improve the usability of the system by introducing facial expressions in ECA for different types of users based on the knowledge and understanding of these users.

The user can interact with the ECA on a web by asking natural language questions in the text-box. The system tries to check the level and preferences of the user and provides the user with the best suitable set of “software services”. Thus a user can reach the goal of choosing desirable software requirements combination. In order to check if the proposed approach produced the expected level of results, a usability study was conducted.

The emotional facial expressions were predicted based on the input of the user or the feedback from the user on the particular question asked by the system. Facial expressions help to keep the user informed about what is happening in the system and how to reach the goal by communicating with an ECA. Different 6 basic emotions are

embedded in ECA and it is shown up on the 3D animated face while interacting with the user. Facial expressions are more self-explanatory in the proposed system and help the users to reach their specific goals according to requirement.

In the empirical testing of the usability of the system, both with and without emotional facial expressions ECA will be tested by users with different level of knowledge from our computer science and other departments. A questionnaire is prepared to understand the user`s interaction with the system. It contains questions related to the comparison between the two systems. It is an online fluid survey. The questionnaires include questions for providing new ideas and suggestions for improving the usability of the system.

Steps of Proposed Usability Testing are as follows:

1. Taking permission from REB (Research Ethics Board) of University of Windsor to conduct Usability study.
2. Selecting participants by sending a mass email about testing the system to all computer science and non – computer science students of University.
3. Providing the proposed system to users on the web for testing.
4. Getting feedback from users by on online fluid survey which contains questionnaires about the proposed system.
5. Analyzing the data of study and calculating results.
6. Report writing of results with graphical representation.

CHAPTER 6

Usability Study Results

6.1 Overview

This chapter is about the usability study which was conducted for evaluating this thesis work by interacting with real users. This study has been granted clearance through the UWindsor Research Ethics Board. Both systems one is text-based without facial expressions of ECA, and second is with facial expressions of ECA were subjected to usability evaluation by the different field of users with varying levels of software development expertise. The students from different departments with different level of software development knowledge have participated in this study through the online fluid survey. Total 126 students from different 3 levels of studies such as Graduate, Professional, and Undergraduate has been participated in this study from different fields such as Computer Science, Biology & Chemistry, Criminology, Law, Business, Philosophy, Psychology, Arts, Faculty of Education, Visual Arts & Communication Media, Engineering, Science, Kinesiology, Political science, Applied Computing, Social work, Earth and Environment science, Human Kinetics, History, Faculty of Nursing, Social relations & families, Social work. Distribution of participants according to their academic level is given in Table 10.

Two Tomcat Apache servers have been set up to provide the system online to all the users for testing. All the related instructions were provided to users in the requested task web page of the survey as given in Appendix B.

Level of study	Participants from different departments
Graduate students	45
Undergraduate Students	73
Professional	8
Total	126

Table: 10 Distribution of participants according to their academic level

6.2 Requested Task Description

The participants had to follow few steps and guidelines while working with the systems. The purpose of the study is explained to the user in the online system. Also, the general functionality of the computer software for online book shopping and the concept of software requirements have been explained. The participants were asked to assume that they need new software to make the bookstore an online bookstore. Task was explained with this simple example and the list of services that they can choose for their new software has been provided in the system. List of services contains 26 services in total same as discussed in experiment *chapter 5*. They were asked to interact with both the ECAs one without any emotions just text base (Existing system) and another with emotional facial expression (Proposed system). The task given to the users is as follows:

1. *Suppose you are an owner of a bookstore who wants to make new software for his/her business to make it the online bookstore, and you are interacting with an agent to create such software for your bookstore. The number of services which you would like to have in your software, you can select during interaction with embodied agent (virtual human) in a natural language.*

2. *Embodied conversational Agent will ask you questions about your requirement of services and you need to select services for your software that you want to make for your business. You can provide your answers in the given text box and notice the facial expressions of an agent.*
3. *Notice if the agent is helping to achieve your goal with appropriate emotional facial expressions and notice the difference between two systems performance.*
4. *Finally, fill survey for feedback.*

In order to calculate other factors in usability study such as effectiveness, efficiency, user satisfaction, and learnability (easiness), the participants were asked to fill up a questionnaire [Appendix A1] and according to their answers, other usability factors was analyzed.

6.3 Questionnaire

The purpose of the questionnaire was to get feedback from the participants so that we can analyze the usability of the system. The questions of the questionnaire were designed from the existing questionnaire tools developed by other researchers as described in usability study *chapter 5, section 5.5*, and also in a way that they provide information about the efficiency, effectiveness, user-satisfaction and issues related to the system. The questionnaire had 11 questions in all. The results gained from the participants' opinion about the system are used to analyze the usability which is described below in detail for each usability factor.

a.) Effectiveness

It is the measure of the extent to which a time system can be expected to complete its assigned mission or objective. First two questions are based on

effectiveness and results are shown in Figure 18 and 19. Total 126 participants give answers to these questions out of it 112 users i.e (88.9%) said “yes” and 14 users i.e (11.1%) said “no” to question 1. For the question 2, 124 people give answers out of which “96” said yes i.e. 77.4% and “28” said “no” i.e. 22.6%. These questions were:

Q1. Did you accomplish the system's objective?

Yes No

Q2. Do the Embodied agent's facial expressions help you obtain a better understanding of the system?

Yes No

For both the effectiveness questions statistics is given below:

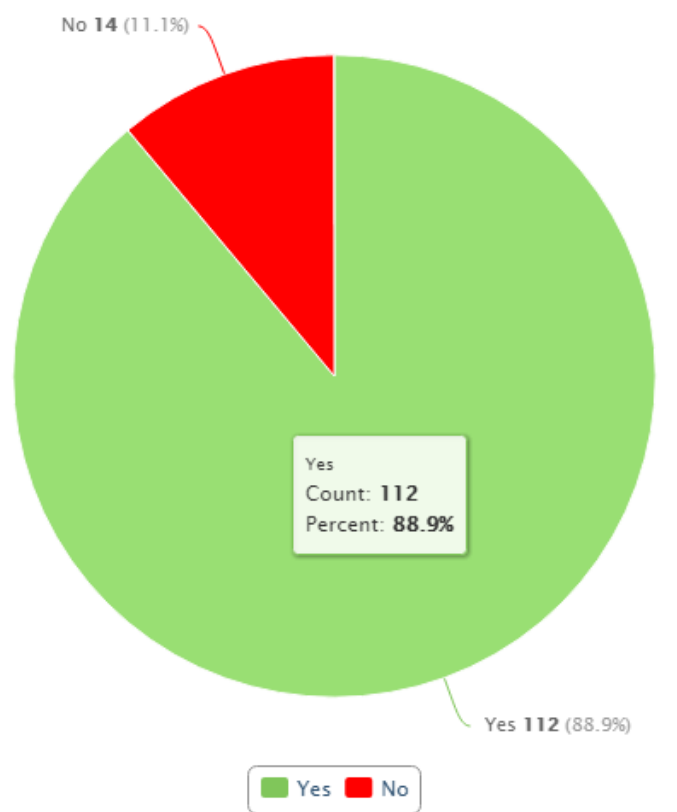


Figure 18: Effectiveness according to all participants based on Q1

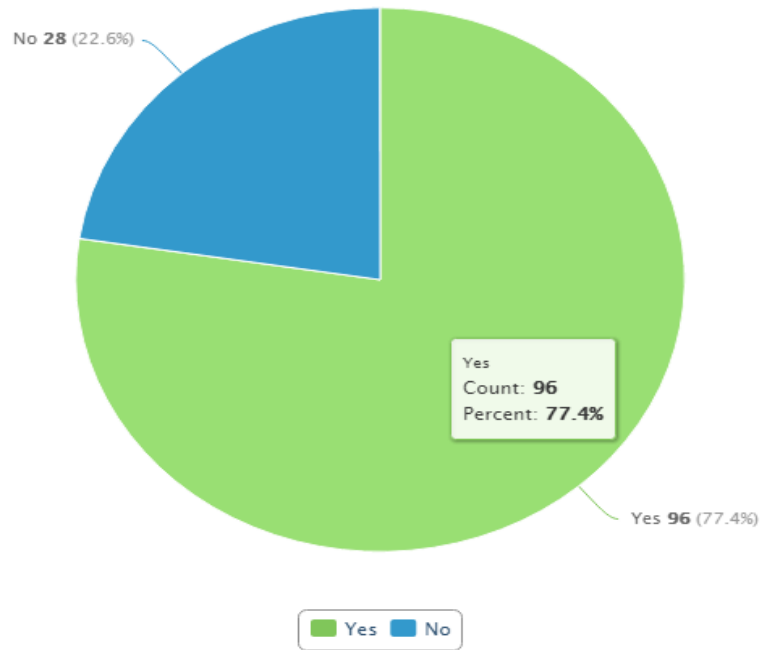


Figure 19: Effectiveness according to all participants based on Q2

From this count and a high percentage of answers with “yes”, reveals that more people found the proposed system effective and they achieved their goal with the help of emotional facial expression of ECA.

b.) Efficiency

Efficiency factor represents a number of tasks that can be done by a user in a specific time unit. Thus efficiency can be calculated from the time expectation level of users. From total no. of participants 124 participants responded to this factor out of which 68 said times taken was “less than expected”, 38 said “as expected”, 18 said, “more than expected”. The question asked was:

Q3: How much time did you spend along the interaction with embodied agent with facial expressions?

a. Less than expected

b. As expected

c. More than expected

User Response	Count	Percentage
Less than expected	68	54.8%
As expected	38	30.6%
More than expected	18	14.5%

Table 11: Distribution of participants for efficiency of system

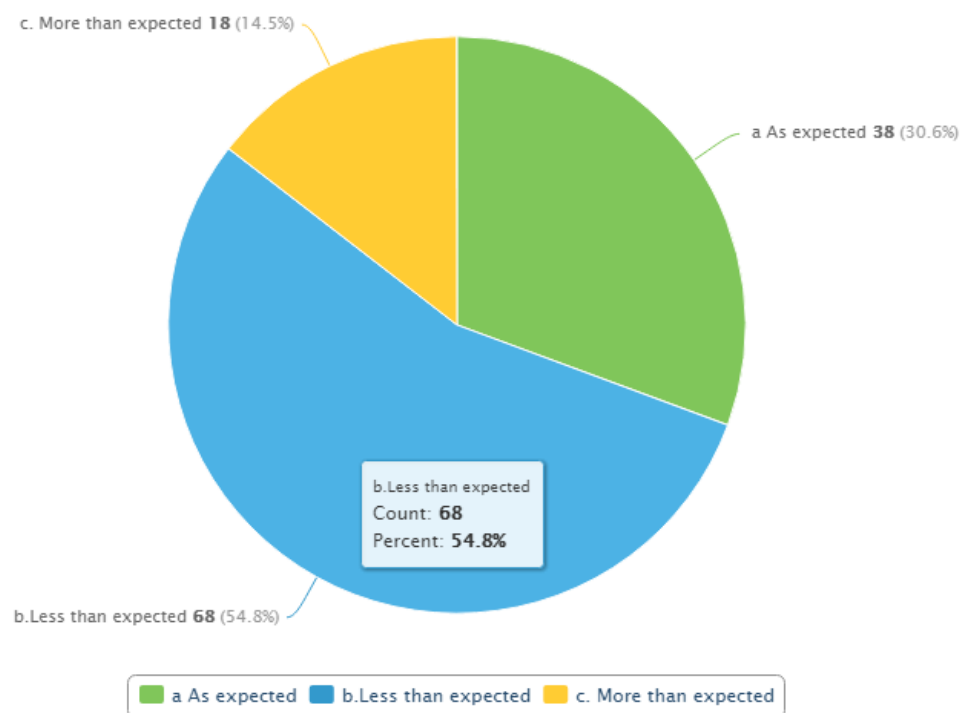


Figure 20: Efficiency of the system based on time taken to achieve goal

Therefore, a vast majority of the students preferred using the proposed system and believe it takes less time to interact and achieve the desired goal.

c.) User satisfaction: The other usability factor, which was evaluated in the study, was user satisfaction. One section of questions in the questionnaires was considered to evaluate the overall satisfaction of the user of working with each system which was

subdivided into 4 questions. In first question, it was asked to the participants to give their overall feedback about their satisfaction by using the system. Out of total 126 users, 123 users responded to this factor. The results were as follows.

User Response	Count	Percentage
Highly satisfied	52	42.3%
Average satisfied	59	48.0%
Low satisfied	12	9.8%

Table 12: Distribution of participants for user-satisfaction of the system

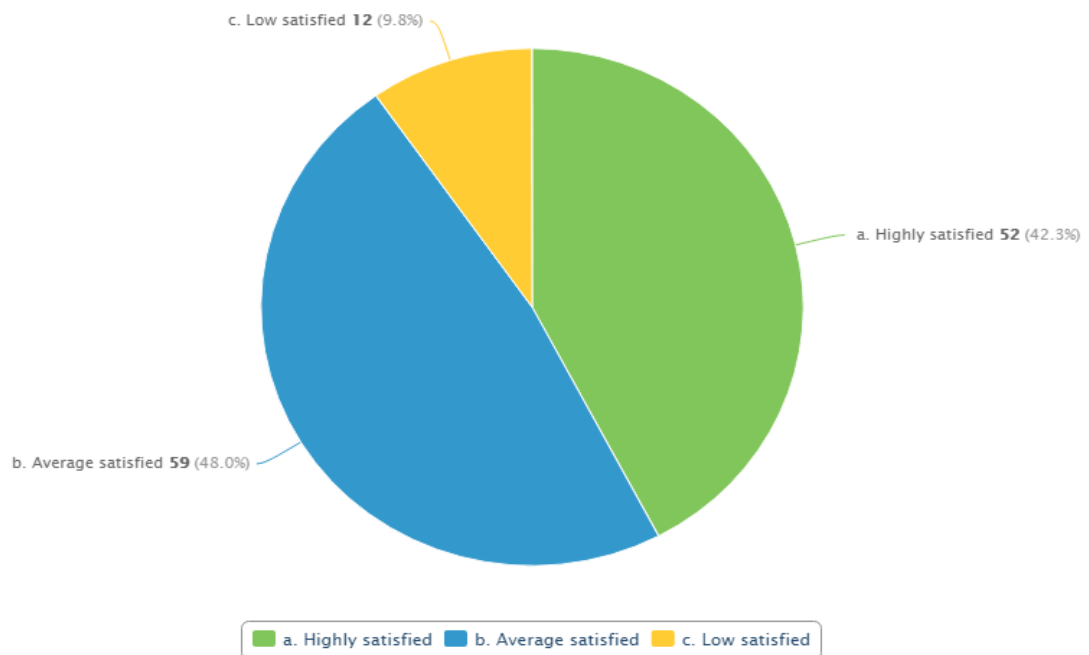


Figure 21: Distribution of participants on their satisfaction level.

Results in Figure 21 shows that user satisfaction level is high and average in majority i.e. 59 users are average satisfied and 52 highly satisfied as compared to low-level satisfaction which is 12 users only. Therefore, the result reveals that most of the users are satisfied with the system.

Another question has been asked to the users for the evaluation of the system from the perspective of user-satisfaction factor and majority of participants said they would prefer ECA system with emotional facial expressions. Results are shown in Table 13 and Figure 21.

User Response	Count	Percentage
With facial expressions ECA	102	82.3%
Without facial expressions ECA	22	17.7%

Table 13: Distribution of participants for user-preference about system

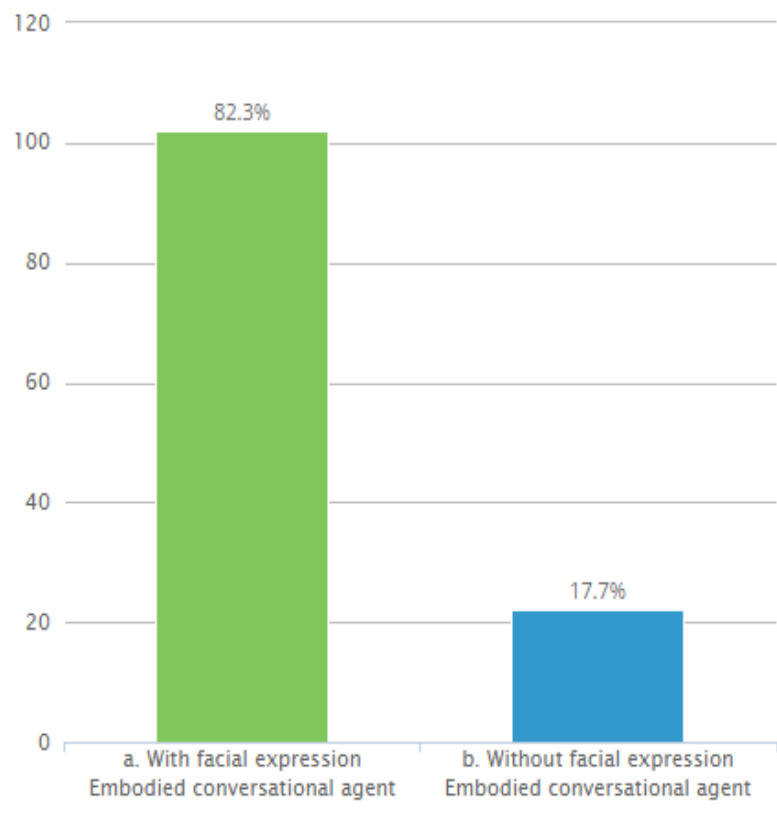


Figure 22: Distribution of participants for preference of ECA with or without facial expressions

Results shown in Figure 22 shows that the 102 participant's i.e (82.3%) preferred ECA system with emotional facial expressions (Proposed system) as compared to another system. Only 22 users i.e. 17.7% users didn't find it as their preference.

Another question in the section of user-satisfaction was asked about facial expressions of ECA whether it helped the users to make better interaction or not as given below:

Q: Do you think that embodied conversational agent's (ECA) facial expressions help you have a better interaction with the system?

a. Yes b. No

User Response	Count	Percentage
Yes	102	83.6%
No	20	16.4%

Table 14: Distribution of participants for helpfulness of system

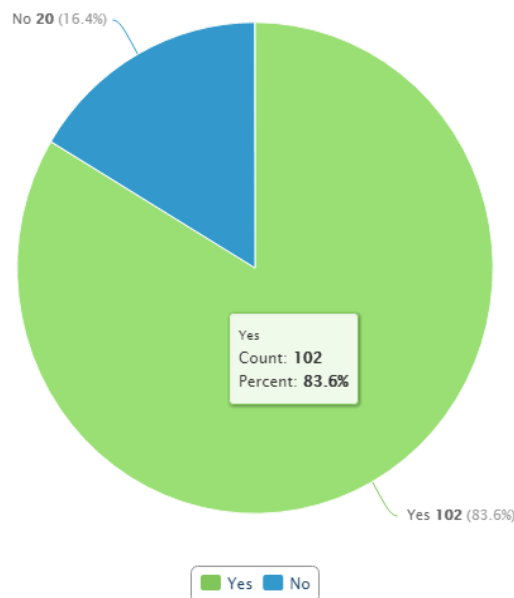


Figure 23: User- satisfaction based on better interaction with facial expressions

The results shown in Figure 23 illustrates that in total 122 users responded to this factor out of which 102 participants i.e. 83.6% found the system better with facial expressions and helpful for interaction with the system and only 20 people i.e. 16.4% of total found it less helpful. Therefore, result illustrates that the proposed system is more helpful as compared to other one and it's more helpful in interaction

Participants were asked the last question about user-satisfaction factor to evaluate the thinking of users about ECA with facial expressions. The question is given below:

Q What do you think about the Embodied conversational agent and its facial expressions?

- *It looks friendly but it needs more conversational movements.*
- *It avoids a tedious interaction.*
- *It is a good support tool.*
- *It helps to personalize the system but it may distract the user from the main objective.*

User Response	Count	Percentage
<i>It looks friendly but it needs more conversational movements.</i>	23	18.9%
<i>It avoids a tedious interaction.</i>	30	24.6%
<i>It is a good support tool.</i>	46	37.7%
<i>It helps to personalize the system but it may distract the user from the main objective.</i>	23	18.9%

Table 15: User- satisfaction based on thinking of user after interaction with system

The Results are shown in Figure 24 as given below in which different users gave their different answers according to their experience with the system and

satisfaction. Out of total 46 users i.e. 37.7% found it a good supporting tool, 30 users i.e. 24.6% said it avoids tedious interaction, 23 users said the system is distracting from the main objective, and rest of the 23 users i.e. 18.9% of the total said it's friendly but still needs improvement. Out of 126 users, only 122 users participated in this question.

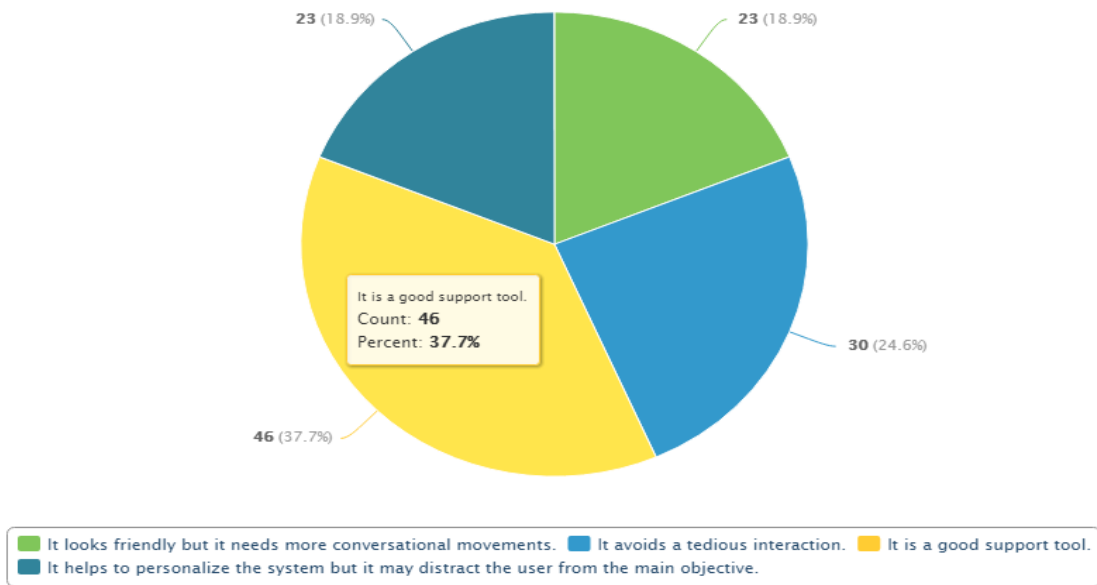


Figure 24: User- satisfaction based on thinking of user after interaction with system

d.) Learnability

As it is mentioned before in chapter 5, learnability is about how fast and easy users can work with a new system for the first time. This factor can address easiness of the system based on user's opinion as well as the user's opinion about his/her understanding of the system. Easiness comes under this factor which is evaluated in this study and results are given below:

e.) Easiness

In the first question, users had been asked to choose the level of easiness of working with the system based on their experience. The answer of the users to this question represents their personal impression about their experience of working with the system. Out of 126 users, only 122 responded to this factor. The results of this question for the proposed system are shown in Figure 25.

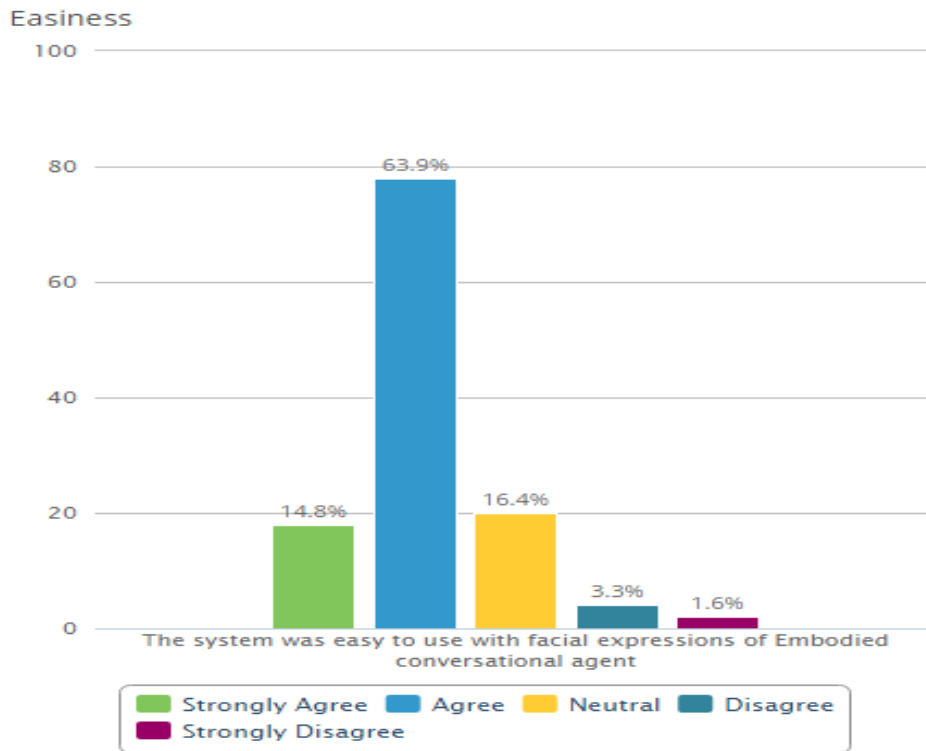


Figure 25: Easiness of ECA with or without facial expressions

Variable	Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree	Total
System was easy to use with facial expressions of ECA	18 (14.8%)	78 (63.9%)	20 (16.4%)	4 (3.3%)	2 (1.6%)	122

Table 16: Distribution of participants for easiness of system

Results of Easiness factor of usability study shows that people found it easy to use in majority i.e. 78 users with 63.9% from total and very fewer people found it not much easy.

f.) Necessity

Another important question that has been asked was if the users think that the emotional facial expressions in an ECA are necessary for the system or not. Basically, this question can show that how users found the emotional facial expressions useful and informative. The answer options for this question were “necessary” for the users who thought that it was helpful, “no difference” for the students that do not look at the ECA and prefer to read the comments of the dialogue interface and “not necessary” for the students that think that it can be confusing and distracting.

Out of 126, only 122 users participated in this factor of usability study. The results of this question were as follows.

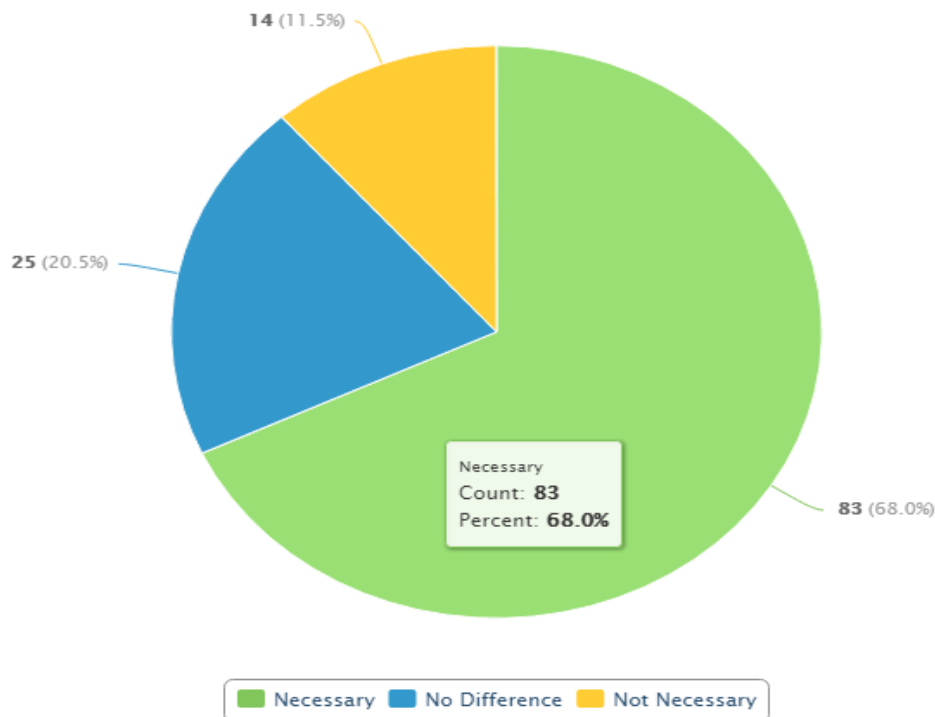


Figure 26: Necessity (percentage) of with facial expression ECA according to users

User Response	Count	Percentage
Necessary	83	68.0%
No difference	25	25.5%
Not Necessary	14	11.5%

Table 17: Necessity of facial expressions in proposed system

In the nutshell, majority of the students were willing to have an ECA with facial expression in the system as a help for a better understanding of the system.

In Table 18, average results for all users are shown with the values of Mean and Standard deviation(STDV) where a low STDV indicates the data points tend to be close to the mean (also called expected value) of the set, while a high STDV indicates that the data points are spread out over a wider range of values.

Usability Factors	Mean (M)	Standard Deviation (STDV)
EFFICENCY	2.4	0.66
USER SATISFACTION	2.3	0.64
NECESSITY	2.5	0.68
LEARNABILITY(Easiness)	3.8	0.79

Table 18: Average results for all the students

g.) Problems and user's overall opinion

In the questionnaire, the last question was about the user's own idea related to advantages and disadvantages of the both the systems. The users were asked about

their opinion regarding what they consider as a problem with the system. Few of the users have provided their feedback to this question. Few users like the interface and ECA, others found the interaction easy with facial expressions but few users said during the interaction with ECA they faced some problems as given below:

- a. Facial expressions are distracting them from the main objective.
- b. More emotions should be embedded for different types of users.
- c. Facial expressions make interaction slower

Few users listed the benefits of the ECA as follows:

- a. Attract the users for interaction
- b. Makes the communication more engaged
- c. Good supporting tool and user-friendly
- d. Emotional facial expressions make the system more naturalistic

In our experiments, all the users first interacted with the system which has without emotions ECA, and later *with emotions ECA*. Although, in general, it is recommended that some interact first without the facial expressions ECA and some with the facial expressions ECA, in our case we wanted the users first to be familiar with the system, and then evaluate the impact of the 3D face with emotions in the interaction.

Thus it can be concluded that the ECA with emotional facial expressions (proposed system) has been successful in improving the user experience with the help of different emotions and by choosing the best suitable facial expressions for a user. On the whole, based on the collected results from both computer science and non-computer science students, it can be concluded that the proposed system improves the

efficiency of the system and makes it more effective by adding emotions in ECA. Also, it makes the system much more attractive and helpful to understand for the users with lesser knowledge about the software development process.

h.) Discussion about improvement and limitations in Usability Study

There are various evaluation and data collection methods available for usability study which can be used for the system evaluation. Those methods could provide different results based on a number of participants from different fields like computer science and non-computer science. As we can assume that computer science people have more knowledge about software's and they can easily understand the application and functionalities as compared to non-computer science students. Data collection methods like interviews, live observations in lab, video analysis during testing can be used to collect data instead of providing online survey. There are various aspects on which usability study can depend that can provide different results as explained below:

Number of participants: The number of participants is more in this thesis for usability study as compared to the previous work as mentioned in *chapter 5, section 5.4.5* in the field of testing ECA with facial expressions as compare to without facial expressions

Participants from different fields: In this thesis, our usability study got replies from different fields such as Computer Science, Biology & Chemistry, Criminology, Law, Business, Philosophy, Psychology, Arts, Faculty of Education, Visual Arts & Communication Media, Engineering, Science, Kinesiology, Political science, Applied Computing, Social work, Earth and Environment science, Human Kinetics, History, Faculty of Nursing, Social relations & families, Social work. So it could be assumed

that students from the different field with a different level of study can have a different point of view about the system that we provided but in this study, we didn't differentiate responses based on fields of study but we have selected the participants from different fields instead of only one field.

Fixed goal: Any fixed goal if we are giving to the users, it will give the potential to the study that every user is using the system for same purpose and goal and evaluation questions are based on the same goal. If the user is giving the answer that he obtained a goal or not it means he is talking about the same goal that every user is talking about in the feedback. If the goal is not fixed than answers and evaluation criteria may vary.

Switching order of system: If comparing the two systems like one existing and another proposed system than the order of the system can also provide us the different feedback from the users. For example: suppose the system is about selecting services from the list and it does not have any ECA emotions. This system is given to the users for testing and then the other system which has emotional facial expressions is given for testing so here we can say that users may already get familiar with the system by using existing one and by adding something more in the form of emotions of ECA may be just some additional information source but the user has impact of using the existing system. Therefore, by switching the system order for testing and by providing the system to different users with switched order may provide gives results different than the study done in this thesis.

Questions can be reversed: Questionnaires should be based on the both systems but not the general questions. Few questions in this study are general for example “did

you accomplish the goal “so these kinds of questions needs to rephrase like “did you accomplish the goal with first system” and similarly can ask for the second system. Therefore questions should be specific for both the systems and options like “yes” and “no” can be reversed in order for different users. For example instead of (yes or no) it could be (no or yes) and questions must be evaluating the performance of both systems if we are comparing two systems.

By considering these points the potential of the usability study can be increased and more accurate results could be obtained in future.

CHAPTER 7

Conclusion and Future work

7.1 Conclusion

In this research, a study has been carried out to conclude that when the users tested an ECA system embedded with emotional facial expressions; it gives the better understanding to users about the system and reduces the effort they need to spend on selecting desired services. This research has been accomplished in a number of steps. Initially, the previous text-based and without emotions ECA system was studied and based on fuzzy logic system the task of facial expression generation on ECA has been implemented such that an appropriate facial expression can be generated according to the requirement which can enhance the user-experience of the overall system by making the system more user-friendly and easy to use. Therefore, from the usability points of view, it has been designed and implemented.

Furthermore, a usability study was conducted on a group of students with different academic backgrounds to justify that the proposed design can positively improve the usability of the user interface. The results of the study show that in overall users had a positive opinion about using proposed ECA with emotional facial expressions. However, based on user's opinions, all usability parameters, which are Learnability, Efficiency, Effectiveness, and User satisfaction have been improved by the proposed ECA comparing to without emotions ECA system. Since we found some contradictions in few users' feedback as few users have more expectations from the system related to the system and facial expressions, it can be concluded that further analysis is required.

7.2 Future Work

Despite the fact that the proposed method improved the usability and quality of the user interface, the results of the usability study show that there is still a lot of scope for improvement. First of all,

- The ECA can be designed in a way that users can have a more direct interaction instead of indirect dialogue-based communication. It would give the users a better feeling of control over the system.
- Different fuzzy input variables more than two can be used to make the system output (facial expressions) more realistic and accurate.
- Advanced modelling techniques are needed to define and justify the fuzzy rule base.
- Other usability study evaluation and data collection method can be used for testing.

APPENDICES

Appendix A

Questionnaires of the Usability Study

The following figures illustrate the questionnaires, which were required to be filled by the participants after working with each of the implemented systems for the purpose of usability investigation.

Embodied conversational agent Usability study

Please tell us about your expertise level in Computer science

Level of study

Department

Please give your feedback by answering following Questionnaires about application.

Effectiveness

Did you accomplish the system's objective?

 Yes No

Does the Embodied agent's facial expressions help you obtain a better understanding of the system?

Efficiency

How much time did you spend along the interaction with embodied agent with facial expressions?

- a. As expected
- b. Less than expected
- c. More than expected

User-Satisfaction

Are you satisfied with the Emotional ECA system ?

- a. Highly satisfied
- b. Average satisfied
- c. Low satisfied

How do you prefer the system to look like (with or without an embodied conversational agent (ECA) and facial expressions)?

- a. With facial expression Embodied conversational agent
- b. Without facial expression Embodied conversational agent

Do you think that embodied conversational agent's (ECA) facial expressions helps you have a better interaction with the system?

What do you think about the Embodied conversational agent and its facial expressions ?

- It looks friendly but it needs more conversational movements.
- It avoids a tedious interaction.
- It is a good support tool.
- It helps to personalize the system but it may distract the user from the main objective.

Necessity

Do you think the Embodied Conversational Agent's emotional facial expressions was necessary for the system ?

- Necessary
- No Difference
- Not Necessary

Easiness

	Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree
The system was easy to use with facial expressions of Embodied conversational agent	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

Your Idea

Write advantages and disadvantages of ECA in the system.

Appendix B

Task description online page of the usability study

The following information illustrates the task description, which were required to be read by the participants before working with each of the implemented systems for the purpose of usability investigation.

TASK TO DO-Please attempt to perform the following tasks on the two Online bookstore systems one Text-Based without facial expression ECA and another with facial expression Embodied conversational agent. Please read the below points carefully to perform the task.

1. Suppose you are an owner of a bookstore who wants to make a new software for his/her business to make it the online bookstore, and you are interacting with an agent to create such a software for your bookstore. The number of services which you would like to provide to your customers you can select while interacting the embodied agent(virtual human), in a natural language.

2. Embodied conversational Agent will ask you questions about your requirement of services and you need to select options for your software that you want to make for your business. You can provide your answers in the given text box and notice the facial expressions of an agent.

3. Questions will be asked by the agent about the basic requirements of Online bookstore.

4. Notice if the agent is helping to achieve your goal with appropriate emotional facial expressions and notice the difference between the text-based system and Embodied conversational system performance.

5. Finally, fill survey for feedback.

After you are done with system testing, please return here and answer the survey questions on the Next page.

Appendix C

Fuzzy Simulation Code

The fuzzy simulation code that was used for creating the facial expressions of ECA is given in this appendix.

```
import java.util.ArrayList;

import java.util.Random;

import java.lang.Integer;

public class Test {

/**
 * @param args
 */

public static final int LIMIT = 10000;

public static int COUNTER = 2;

public static void main(String[] args) {

int ncp = (new Random()).nextInt(LIMIT);

Test.show("ncp: "+ncp);

ArrayList<Double> ncpList = Test.fuzzification(4, ncp);

int reward = (new Random()).nextInt(LIMIT);

Test.show("\nreward: "+reward);

ArrayList<Double> rewardList = Test.fuzzification(3, reward);

double[] inf = Test.inference(ncpList, rewardList);

double sum = 0;

for(int i=0;i<inf.length;i++){

sum += inf[i];

}
```

```

Test.show("\n"+(double)(inf[8]+inf[9])/sum+
Happy\n"+(double)(inf[6]+inf[10]+inf[11])/sum+" Surprise");
Test.show((double)(inf[5]+inf[7])/sum+ " Sad\n"+(double)(inf[1]+inf[2])/sum+
Anger");
Test.show((double)(inf[3]+inf[4])/sum+ " Fear\n"+(double)(inf[0])/sum+
Disgust");
}

public static ArrayList<Double> fuzzification(int segments, int value){
ArrayList<Double> result = new ArrayList<Double>();

int limit = 0;

int intersection = 3;

for(int i=0;i<segments;i++){
Test.show("SEGMENT "+i);

int a, b, c, d;

if(limit!=0)a = (new Random()).nextInt(limit);

else a = Test.getRandom(limit);

b = Test.getRandom(a);

c = Test.getRandom(b);

d = Test.getRandom(c);

if(COUNTER>0)COUNTER--;

limit = d - (new Random()).nextInt(intersection);

Test.show("a: "+a+", b: "+b+", c: "+c+", d: "+d);

double temp = Math.min((double)(value-a)/(b-a), (double)(d-value)/(d-c));

double ans = Math.max((double)Math.min(temp, 1), (double)0);

Test.show("F("+i+"): "+ans);

```

```

result.add(ans);
}
return result;
}

public static double[] inference(ArrayList<Double> ncp, ArrayList<Double>
rewards){
double[] result = new double[ncp.size()*rewards.size()];
for(int i=0;i<result.length;i++){
int offset = i%ncp.size();
result[i] = ncp.get(offset) + rewards.get(i/ncp.size()) -
(ncp.get(offset))*(rewards.get(i/ncp.size()));
Test.show("W"+(i+1)+": "+result[i]);
}
return result;
}

public static int getRandom(int minLimit){
Random random = new Random();
while(true){
int num = random.nextInt(LIMIT)/(int)Math.pow(10, (double)COUNTER);
if(num>minLimit){
return num;
}
else continue;
}
}
}

```



```
public static void show(String text){  
    System.out.println(text);  
}
```

REFERENCES

- [1] Adarsh, S. and Janga Reddy, M., 2015. Trend analysis of rainfall in four meteorological subdivisions of southern India using nonparametric methods and discrete wavelet transforms. *International Journal of Climatology*, 35(6), 1107-1124.
- [2] Ahn, H. and Picard, R.W., 2006. *Affective cognitive learning and decision making: the role of emotions*, 1-6.
- [3] Ali, O.A.M., Ali, A.Y. and Sumait, B.S., 2015. Comparison between the Effects of Different Types of Membership Functions on Fuzzy Logic Controller Performance. *International Journal*, 76.
- [4] Archevapanich, T., Purahong, B., Klingajay, M. and Sooraksa, P., 2006, October. Facial visualization for robotic indicator by using fuzzy emotional system. In *2006 SICE-ICASE International Joint Conference*, IEEE, 5634-5637.
- [5] Bay, Y. and Wang, D., 2006. Fundamentals of fuzzy logic control—fuzzy sets, fuzzy rules and defuzzifications. In *Advanced Fuzzy Logic Technologies in Industrial Applications*, Springer London, 17-36.
- [6] Baecker, R.M. ed., 2014. *Readings in Human-Computer Interaction: toward the year 2000*. Morgan Kaufmann.
- [7] Blewitt, W., Ayesh, A., John, R.I. and Coupland, S., 2008, May. A millenson-based approach to emotion modelling. In *2008 Conference on human system interactions* 491-496. IEEE
- [8] Blewitt, W., 2012. Exploration of emotion modelling through fuzzy logic.
- [9] Bosse, T., Broekens, J., Dias, J. and van der Zwaan, J., 2014. Emotion Modeling.
- [10] Bui, T.D., 2004. Creating emotions and facial expressions for embodied agents.
- [11] Bui, T.D., Heylen, D. and Nijholt, A., 2003, May. Improvements on a simple muscle-based 3D face for realistic facial expressions. In *Computer Animation and Social Agents, 2003. 16th International Conference on IEEE*, 33-40.
- [12] Creed, C., Beale, R. and Cowan, B., 2015. The Impact of an Embodied Agent's Emotional Expressions over Multiple Interactions. *Interacting with Computers*, 27(2), pp.172-188.
- [13] Collier, G., 2014. *Emotional expression*. Psychology Press.
- [14] De Melo, C.M., Gratch, J. and Carnevale, P.J., 2015. Humans versus Computers: Impact of Emotion Expressions on People's Decision Making. *IEEE Transactions on Affective Computing*, 6(2), 127-136.

- [15] El-Nasr, M.S., Yen, J. and Ioerger, T.R., 2000. Flame—fuzzy logic adaptive model of emotions. *Autonomous Agents and Multi-agent systems*, 3(3), 219-257.
- [16] Esau, N., Kleinjohann, L. and Kleinjohann, B., 2005, September. An Adaptable Fuzzy Emotion Model for Emotion Recognition. In *EUSFLAT Conf*, 73-78.
- [17] Fuzzy control programming. Technical report, International Electrotechnical Commission, 1997.
- [18] Hewett, T.T., Baecker, R., Card, S., Carey, T., Gasen, J., Mantei, M., Perlman, G., Strong, G. and Verplank, W., 1992. *ACM SIGCHI curricula for human-computer interaction*. ACM.
- [19] Heylen, D., Poel, M. and Nijholt, A., 2001, December. Generation of facial expressions from emotion using a fuzzy rule based system. In *Australian Joint Conference on Artificial Intelligence*. Springer Berlin Heidelberg, 83-94.
- [20] Holden, R.J., Voidsa, S., Savoy, A., Jones, J.F. and Kulanthaivel, A., 2016. Human Factors Engineering and Human–Computer Interaction: Supporting User Performance and Experience. In *Clinical Informatics Study Guide*. Springer International Publishing. 287-307.
- [21] Hsu, Y.T., Leu, F.Y., Liu, J.C., Huang, Y.L. and Chu, W.C.C., 2013, October. The Simulation of a Robot with Emotions Implemented with Fuzzy Logic. In *Broadband and Wireless Computing, Communication and Applications (BWCCA), 2013 Eighth International Conference on IEEE*. 382-386.
- [22] Hussain, A. and Kutar, M., 2009. Usability metric framework for mobile phone application. *PGNet, ISBN, 2099*, 978-1.
- [23] <http://pomdp.org> [Last accessed on: 26/07/2016].
- [24] <http://facegen.com/index.htm> [Last accessed on: 26/07/2016].
- [25] http://facegen.com/modeller35_help.htm [Last accessed on: 12/06/2016].
- [26] http://cs.bilkent.edu.tr/~zeynep/files/short_fuzzy_logic_tutorial.pdf [Last accessed on: 22/07/2016]
- [27] [https://en.wikipedia.org/wiki/Membership_function_\(mathematics\)](https://en.wikipedia.org/wiki/Membership_function_(mathematics)) [Last accessed on: 17/03/2016]
- [28] Izard, C.E., 2013. *Human emotions*. Springer Science & Business Media.
- [29] Johnson, M., 2013. Usability test results for Encore in an academic library. *Information Technology and Libraries (Online)*, 32(3), 59.

- [30] Kaler, M.S.2014. An interactive approach to software visualization for customization. Electronic Master's Theses and Dissertations, CS Dept. UWindsor, Windsor, ON, 5161, 1-102.
- [31] Kortum, P. and Sorber, M., 2015. Measuring the usability of mobile applications for phones and tablets. *International Journal of Human-Computer Interaction*, 31(8), 518-529.
- [32] Kowalczyk, Z. and Czubenko, M., 2016. Computational Approaches to Modeling Artificial Emotion—An Overview of the Proposed Solutions. *Frontiers in Robotics and AI*, 3, 21.
- [33] Lee, S.H., 1999. Usability testing for developing effective interactive multimedia software: Concepts, dimensions, and procedures. *Educational Technology & Society*, 2(2), 1-13.
- [34] Lin, H.X., Choong, Y.Y. and Salvendy, G., 1997. A proposed index of usability: a method for comparing the relative usability of different software systems. *Behaviour & information technology*, 16(4-5), 267-277.
- [35] Liu, Z. and Pan, Z.G., 2005, October. An emotion model of 3d virtual characters in intelligent virtual environment. In *International Conference on Affective Computing and Intelligent Interaction*, Springer Berlin Heidelberg, 629-636.
- [36] Liu, Z., He, S. and Xiong, W., 2008, September. A fuzzy logic based emotion model for virtual human. In *Cyberworlds, 2008 International Conference on IEEE* 284-288.
- [37] Mimoun, M.S.B., Poncin, I. and Garnier, M., 2012. Case study—embodied virtual agents: An analysis on reasons for failure. *Journal of Retailing and Consumer services*, 19(6), 605-612.
- [38] Mendel, J.M., 1995. Fuzzy logic systems for engineering: a tutorial. *Proceedings of the IEEE*, 83(3), 345-377.
- [39] Mulpuri.V.K, 2016. Trend Analysis of Belief-State History with Discrete Wavelet Transform for Improved Intention Discovery. Electronic Master's Theses and Dissertations, CS Dept. UWindsor, Windsor, ON, Canada.
- [40] Myers, D.G., 2004. Theories of emotion. *Psychology: Seventh Edition, New York, NY: Worth Publishers*, 500.
- [41] Noy, N.F., 2001. Ontology Development 101: A Guide to Creating Your First Ontology: Knowledge Systems Laboratory, Stanford University. *Stanford Knowledge Systems Laboratory Technical Report KSL-01-05 and Stanford Medical Informatics Technical Report SMI-2001-0880*.
- [42] Ngo, T.D. and Bui, T.D., 2015, January. A Vietnamese 3D taking face for embodied conversational agents. In *Computing & Communication Technologies-Research, Innovation, and Vision for the Future (RIVF), 2015 IEEE RIVF International Conference*, 94-99.

- [43] Nielsen, J., 1992. The usability engineering life cycle. *Computer*, 25(3), 12-22.
- [44] Ortony, A., Clore, G.L. and Collins, A., 1990. *The cognitive structure of emotions*. Cambridge university press.
- [45] Paz, F. and Pow-Sang, J.A., 2016. A Systematic Mapping Review of Usability Evaluation Methods for Software Development Process. *International Journal of Software Engineering and Its Applications*, 10(1), 165-178.
- [46] Palmeri, S., 1993. The effectiveness of animated demonstrations for computer-based tasks: a summary, model and future research. *Journal of Visual Languages & Computing*, 4(1), 71-89.
- [47] Peters, E., Västfjäll, D., Gärling, T. and Slovic, P., 2006. Affect and decision making: A “hot” topic. *Journal of Behavioral Decision Making*, 19(2), 79-85.
- [48] Plutchik, R., 1991. *The emotions*. University Press of America.
- [49] Polikar, R., 1999. The story of wavelets. *Physics and modern topics in mechanical and electrical engineering*, pp.192-197.
- [50] Qamar, S. and Ahmad, P., 2015. Emotion Detection from Text using Fuzzy Logic. *International Journal of Computer Applications*, 121(3).
- [51] Ricaño, Y., Hernandez, J., Sucar, L.E. and Mayora, O., 2005, August. User preferences for effective task completion while interacting with a robotic conversational animated face. In *ROMAN 2005. IEEE International Workshop on Robot and Human Interactive Communication*, 478-483.
- [52] Sadri, V. 2012. A Petri-Net Based Approach of Software Visualization for Software Customization. *Electronic Master's Theses and Dissertations, CS Dept. UWindsor, Windsor, ON*.
- [53] Stanton, N.A., Ashleigh, M.J., Roberts, A.D. and Xu, F., 2001. Testing Hollnagel's contextual control model: Assessing team behaviour in a human supervisory control task. *Journal of Cognitive Ergonomics*, 5(1), 21-33.
- [54] Weiss, B., Wechsung, I., Kühnel, C. and Möller, S., 2015. Evaluating embodied conversational agents in multimodal interfaces. *Computational Cognitive Science*, 1(1), 1.
- [55] Yang, X. and Chen, G., 2009, March. Human-computer interaction design in product design. In *Education Technology and Computer Science, 2009. ETCS'09. First International Workshop on IEEE*. 437-439.

- [56] Yuan, x.and vijayarangan, r., 2013, August. Emotion Animation of Embodied Conversational Agents with Contextual Control Model. In *Green Computing and Communications (GreenCom IEEE International Conference on and IEEE Cyber, Physical and Social Computing*, IEEE, 670-677.

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