NEURO-BIOLOGICAL EMOTIONALLY INTELLIGENT MODEL FOR HUMAN INSPIRED EMPATHETIC AGENTS

A. Shabbir, M. Shabbir, M. Rizwan and F. Ahmad

***Abstract*—** Social relationship quality rates our social interaction. Evaluation of emotional situation and identification of effective responsive strategy for currently observed situation management is dependent to social interaction and interpersonal relationship quality. According to functional perspective on emotion, to adapt and navigate the social environment 'affective responses 'assist individuals. Emotional Intelligence (EI) is a cognitive intelligence. For humanizing social interaction, we propose a neuro-biological emotional intelligence model covering six basic primary emotions for natural human-machine interaction, which captures extrinsic inputs through sensory receptors, and after processing, recalling prior memories, map those inputs to current exposition in order to exhibit an adaptive emotional behavior using Artificial Neuro Fuzzy Inference System Technique.

***Keywords*—** *Neuro-Biological, Social Interaction, Emotional Intelligence, Humanoid Robots.*

1. INTRODUCTION

THE theme of this research falls within the area of "Artificial intelligence" a subfield of "Affective computing". The latest division of "computer science" emerged with "Rosaling Picard's paper", from where "Affective computing" [1-4] can be defined as " computing that identifies with, emerges from or impacts emotions" It is a cross-disciplinary area extending "computer science", "psychology", "physiology" and "cognitive sciences". Researches and findings of neurobiology and many other scientific disciplines regarding feelings and emotions have attracted many researchers towards applied science and AI. Main interest of these areas or new scientific thoughts that emotions play a key role in human psychological processes [5].In this paper I have to wrestle with hazy, psychological, relatively unscientific term "emotions" [6].We as a human being obey our emotion unconsciously .Emotions shape our personality. They define the way of perception. Human beings are complex species with high emotional and reasoning skills. People with high reasoning skills are more intelligent [7].Emotional intelligence provide a sense of competency in any field .It is a combination of social, practical and personal intelligences. They operate on hot cognitive processes [8].Emotion and cognitions are highly integrated for creating sense of reasoning, decision-making, learning and other adaptive behaviors. Their integration results in intelligent behaviors [9]. Emotion play a vital role in creating and regulating relationship [10].Emotions synchronize our two individuals' brain activate and promote social interaction [11].Emotional regulation abilities enhance the quality of social interaction. Emotional regulation can proceeds through cognitive, behavioral, expressive and psychological abilities [12]. Emotions facilitate communication ability and social functions, which helps to percept about other's feelings, thoughts, intentions and many other social encounters. There are many performance-based tests for emotional competency [13].

Especially emotional expression (facial expression) affect observer's behavior [14]. Therefore, positive relationship at any workplace lie between managing emotions and social interaction quality [13].Science fiction is full of emotional machines .People sometime shout and get angry at machines but they even take notice or realize it. They neither feel your emotions nor recognize you. Human –Robot interaction that specializes in interaction between machine and man. Researcher's intention is to develop emotions and reply to emotions with new sensors and technologies. Because emotion and feelings are the simplest way to boost developments [5]. This research is primarily intending to facilitate emotions in "Artificial agents" with the conclusive goal to intensify its autonomic behavior. It will enhance the agent's flexibility, robustness and self-sufficiency.

2. LITERATURE rEVIEw

This is not the question can intelligent machines have any emotion? However, in fact it is, can machines be intelligent without any emotions? [6].

There is no central system in brain for emotions. Different brain parts integrate and work to create different aspects of emotions. No one part of them is specialize for cognitive and emotional processes, most of them called non-cognitive functions .Emotions dynamically arise in a sequential fashion depending upon past memories. The function of emotion is to attain simplified but highly impacted communication. Robots can have robot-emotion just as if animals have animal-emotions. Neuro modulation had presented a new way to characterize and quantify the emotional dynamics. It offered a new way to have an account of,

1. Lack of central emotional system in brain.
2. Unusual interdependence between cognition and brain.
3. Basic emotion's emergence.

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4. Close relationship between pharmacological challenges and dynamic emotional nature.
5. Time scale difference between emotions and cognition and between emotions.

Neuro modulation fulfills most of the constraints. At operating system level some neuro modulation aspects could be implemented for creating robot behavior by having a system wide control pf some parameters [15]. Not just productive artificial agents but also the agents who can interact appropriately with humans have the ability to learn, act upon, their own experience and perception of everyone's response. Since, morphologically and structurally they have no evolutionary and self-organized processes. So, grounding emotions and cognitions in robots is a challenging task [16].

Whole research work on neurobiology of emotions result in deep understanding of neural mechanisms and brain structures. The paper [17] has presented different kinds of emotions , ethology to robot motivation, many cognitive architectures, core neurobiological structure for emotions, neuro modulation of robot emotions.

Ethological models for animal behavioral study and how this relates to the concept of drives and incentives and inspires the basic emotional responses. Similar to cathexis system. A unified approach is necessary for assessing conditions and represent emotional state and facial expressions accordingly. Cathexis does not offer unified approach for handling all these .Cathexis models our emotions it does not provide methodology for creating expressions. Cathexis model focuses on emotion-based control where emotions are a key role in behavior generation. This paper focused on emotions and expression role socially. Kismet robot not just communicate well but interact with full social competency and it is treated as a social creature. It is necessary that robot not just do the right, but also at right time and in a right way. For this emotional and expressive system should work properly. They had adopted a unified approach with all affective states were commonly represented.

1. Assessing eliciting condition.
2. Emotional representation.
3. Facial expression generation

Factor's myriad were converted using somatic markers [18]. Behavior-based robots have the ability of motivation and emotion. The paper [6] has presented some roles for robot provided by motivation/emotion. Toleman's psychological model, motivational behavior generation, computational attachment model by drawing safe and comfort zone around the robot. Some robotic experiments, ethological study for human-robot interaction and a trait model TAME with four personality traits were also discussed.

SVM "Smart Virtual Worker" had presented an opportunity that how workflow parameters can be replicated inside virtual simulations .So that during production planning different construction and storage mechanisms can be establish. This emotional model works with two neural inputs

1. "Planned action from reinforcement learning algorithm"
2. "Signals from body and robot actuators" for proper functioning.

Ergonomic system for producing signal from body. Three factors C, S, E, which are constitution, sensitivity and experience, were used in this model. Three valence scale labeled "sympathetic arousal, Joy and fear" used here for emotional state. At last, "reward for reinforcement learning algorithm "was presented [19].

The paper [20] has discussed an overview of robotic emotions .What are the possibilities that robot learn through emotions? , How robot can recognize emotions? , issues against emotional robot interaction in society, a system architecture for emotional system in intelligent robots was proposed in this paper. Inspired by "Human Love" Science, this paper [21] has presented an advanced artificial intelligent "lovotic robot "system with three modules.

1. "AES (Artificial Endocrine system)" based on "love psychology".
2. "PLA (probabilistic love assembly)" based on "love psychology".
3. Emotion based AST (Affective state transition).

For creating realistic behavior, these three modules work together.

A review on Emotional robots, robot artists, emotions, emotional models, some already implemented emotional robots e.g. kismet and related architectures were discussed [22]. They proposed a new category of robot and their use in art-field, expressing emotions from text to drawings. The idea was to build drawing robot to express emotions through faces drawn by him and to represent emotions in text. At last, a virtual implementation of emotional robots was presented.

Robot that expresses emotions through affective interaction KOBIE [23]. Through some affective stimuli i.e. 'hit', 'stroke', 'embrace', 'pock' they proposed a method for emotional expression. Emotional engine, "Needs model" with step layer, Mood model with internal and external stimuli, Emotion motive generation, Emotion factor table and Emotional model was presented.

They presented KOBIE as an intelligent emotional robot and how it expresses emotion through affective touch for interactive communication. [24] presented function of autonomous agent WAMOEBA-2R and "99 international robot exhibition". Interaction between human and autonomous robot was discussed through a new concept. We can use these robots in homes and hospitals. Communication system presented in this paper further needed to address e.g. methods for human empathy, human-friendliness toward robots.

LEGO robot was built for successful emotional reaction. Two techniques to achieve this goal were adopted.

1. In children's interaction significance of physical manipulation
2. Inspiration was drawn by basic theories of emotional intelligence with associated common facial expressions.

By keeping these ideas in mind, Feelix "Humanoid robot LEGO" was built with different Interactive facial expressions [25]. From HCI to HRI, to create social interactive capabilities in human-computer model for achieving human –robot socially interactive models. Not just interaction but also "Human-robot visual interaction" and "Human-robot vocal interaction". Norman proposed action theory involves modeling cognitive processes. Execution and Evaluation process completes in seven stages.

In human-robot interaction, human –computer interaction community progresses can help us a lot. Execution of feelings, expressions for robotic emotion’s simulation and recognizing emotional expressions are the key factors for generating emotional intelligence [26].

Building an” Emotional Enthusiastic Head robot with behavioral decisions and face detection” that not just interact with human but also help in their daily routine tasks e.g. at homes, hospitals, supermarkets, offices etc. [27] for this purpose robot must have a friendly character and personality.” PIL Head robot” with a face recognition based on “Support Vector Domain Description (SVDD)”, gesture recognition,” emotional behavior decision model”, facial emotional expression by 3D robot character [28]. How a control architecture can be developed to create a natural interaction between human and robot? To show “Human like behavior” 3 major parts

1. Emotion
2. Action
3. Drive

Different sensors and actuators to have a successful communication with environment. “Humanoid Robot Head ROMAN” was developed to show natural communication behavior and drive exploration [29]. For an effective interactive communication, not just intrapersonal emotional skills but also interpersonal skills (social competency) play an important role. [30] Has argued that it requires a “layered Emotional Alignment model”.

1. “Conceptual emotional alignment”
2. “Schematic emotional alignment”
3. “Automatic emotional alignment”

For humanoid and semi-humanoid robot, emotional intelligence is proposed by [31]. A “Hypothetical human robot” can have sensors and actuators, LEDS, motors and “database design” is needed for emotional intelligence implementation. Quality of interaction determines effective collaboration and acceptance level in society. This system requires two major parts.

1. Through “ARTMAP neural network” for learning human emotional expressions.
2. Implementing that “personalized emotional model” to socially interactive robots.

A new methodology for personalized gesture’s construction for different emotional state representation was proposed in [32]. Emotions play a vital role in decision-making. [33] Proposed that two things are necessary for “affect aware” robots.

1. Affective inference
2. Learning from affect

“Unified macro-model of cross disciplinary system architecture” was analyzed by [34] against the “need – motivation behavior framework”. Some challenges and recommendations regarding the “artificial psychology” and “artificial emotions” e.g.” singular valley evaluation of humanoid robots” for the judgment of robot suitability, lack of emotional model in-depth research etc. were also discussed.

“Socially intelligent Robots: dimensions of robot interaction” by [35] has presented an introduction of HRI regarding social intelligence in human and robots. Conceptual framework development with the help of two HRI projects case studies for the framework illustration and human robot relationship with different paradigms e.g. “cartarker paradigm” and “assistant paradigm” were also discussed. The fundamental source by which human and robot acquire abilities of flexible behavior for complex multiple tasks with different conditions is “hierarchical organization of behavior”. Main focus of research in neuroscience and psychology areas is to find evidence that the key organization principles of behavior and brain are hierarchy and modularity [36].

A review of “socially interactive robots “that are necessary for human –robot interaction. Some “human-human” characteristics e.g.” express and perceive emotion”,” communicate with high level dialogue”,” learn/recognize models of other agents” etc. were discussed.

Some methodologies (e.g. “design approaches”, “biologically inspired” for internal simulation of social behavior in robots,” functional designed” for outward intelligent social behavior with three techniques),” morphology” (with “design consideration”,” Anthropomorphic”, “Zoomorphic”,” Caricatured” and functional perspective) were presented. “Speech, facial expression and body language” role for emotional representation and concepts regarding dialogue, personality,” human oriented perception” with different types of perception e.g. “people tracking”,” speech recognition”,” gesture recognition”, “facial perception” were also discussed. User modeling constitutes two basic types” cognitive” and “attentional”.” Socially situated learning” covers many types of learning e.g. “Robot social learning” and “Imitation” for learning behavior etc. Intentionality covers understanding behavior with attention and expressions [37].

In perceiving actions, motor system of observer primarily involves. The paper [38] has presented an over view of HAMMER (“Hierarchical Attentive Multiple Models of Execution and Recognition”) according to this motor system organization is distributed and hierarchical.

1. “competitively selecting and executing an action”
2. “perceiving it when performed by a demonstrator”

Perceiving actions for “top-down control of attention”, such a particular arrangement is a principled approach.

A generic model of mood, personality and emotion simulation for virtual conversational humans with updating mechanism for emotional behavior. How framework can be generated existing appraisal theories? At last a prototype system was described in which existing models with talking heads, dialogue system, “synchronized speech” and “facial expressions “were discussed [39].

“Smart Virtual worker” (SVW) project had presented an approach for replicating virtual simulation with a workflow parameter from alternative routes,” construction methods” for production planning. SVW with many standalone modules, emotional model is one of them. This emotional model covers three emotional states sympathetic arousal, joy, anger [19]. Emotional model presented by “Center of intelligent technologies” covers overall emotional responsive sense.

Our proposed model covers six basic primary emotional states under neuro-biological, psychological and cognitive processes utilizing Artificial Neuro Fuzzy Inference System. In [41] has presented model for emotion detection based on facial expressions and [42] paper has categorize emotions based on audition properties but our research has proposed a neurobiological approach using ANFIS and it covers both facial expression as well as audition attributes.

3. EMOTIONAL INTELLIGENCE MODEL

The complete working of our proposed EI computational model based on the neurobiological study of emotional originating part of human brain i.e. Limbic system, along with few psychologically features for the entire emotion regulation in robotics is narrated in this section.

3.1. Sensory Stimulus

Stimulus is an observable change in external or internal environment. It elicits a specific reflex. An agent's ability to respond to external stimulus is called "Susceptibility". It acts as a basic for generating perception. "Stimulus filtering "allows to filter and respond to significant stimulus to avoid responding to unimportant stimulus.When we see something in environment we detect and select that stimuli from environment. "Distal stimulus "is the actual physical stimulus around us reach to our senses."Proximal stimulus" stimulus that has been registered/entered through sensory receptors.That sensory stimuli can be of two types:

1. Interoceptive
2. Exteroceptive

Interoceptive is the one that is derived from inside the body. A stimulus from inside the body in robot's perspective can be due to its processor state, battery state and O.S etc. All of the three components will regulate a cardiac process that also affects our energizing level (activation level). While exteroceptive stimulus that is derived from outside the body (externally). Exteroceptive stimulus involves the detection of three types of sensory inputs i.e. Visual, auditory and hap-tic (known as sensory modality).

3.1.1. Visual

Visual sensory system may constitute "structured light 3D scanner "," Thermographic camera", "Hyperspectral imager"," Radar imaging Lidar scanner", "magnetic resonance image"," Side scan SONAR", "Synthetic aperture SONAR" sensors for detecting "proximal mode" or "Tactile mode", sensors for detecting absence or presence of object.

3.1.2 Auditory/Acoustic

Auditory sensory system involves some sort of machine learning and signal processing for extracting useful information from listening different sounds, it may constitute microphone with some algorithms for

1. Representing your captured sound
2. Organizing /separation
3. Identifying /classifying/Recognizing
4. Modeling
5. Showing response

3.1.3 Haptic/Touch

Haptic sense requires such sensors with movement and temperature detection and distinguishing between forms of touching object with high flexibility.
Stimulus that is sensed through these organs resides in the regarding portion of sensory memory e.g. visual contents in iconic memory, Auditory contents in echoic memory and haptic content in haptic memory.

3.2. Iconic memory/visual memory store

Representation of visual stimulus mentally known as "Icons". Therefore, iconic memory will act as a kind of buffer for processing that Visual sensory input probably for 2-3seconds.

3.3. Echoic Memory

A kind of sensory memory store ("holding tank") for the representation of hearing sensory stimulus acts as a buffer for storing acoustic input for 3-4 seconds to properly process it.

3.4. Haptic Memory/Haptic Store

Input from touch sensors in agents to maintain the sense of touch physically. Haptic memory will store the information about

1. Type of touch
2. Temperature
3. Vibration
4. Pressure

After processing it.

3.4.1. Processing

From agent's perspective, processing involves:

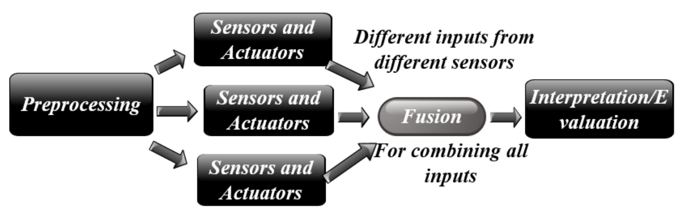

Fig.1. Processing

a) Preprocessing:May include

1. "Colloquially ": Before using sensors, previous reading must be clean.
2. Filtering Stimulus filtering e.g. Reduction of surrounding noise by mapping the speech with facial expressions.
3. Finding "Basic Stuff" e.g. Detection of specific edge in visual sensory system.
4. Data representation changing (transformation).
5. All these are part of sensory memory and this whole system is called sensory neuro system in which stimulus is sensed through receptors (sensory organs).

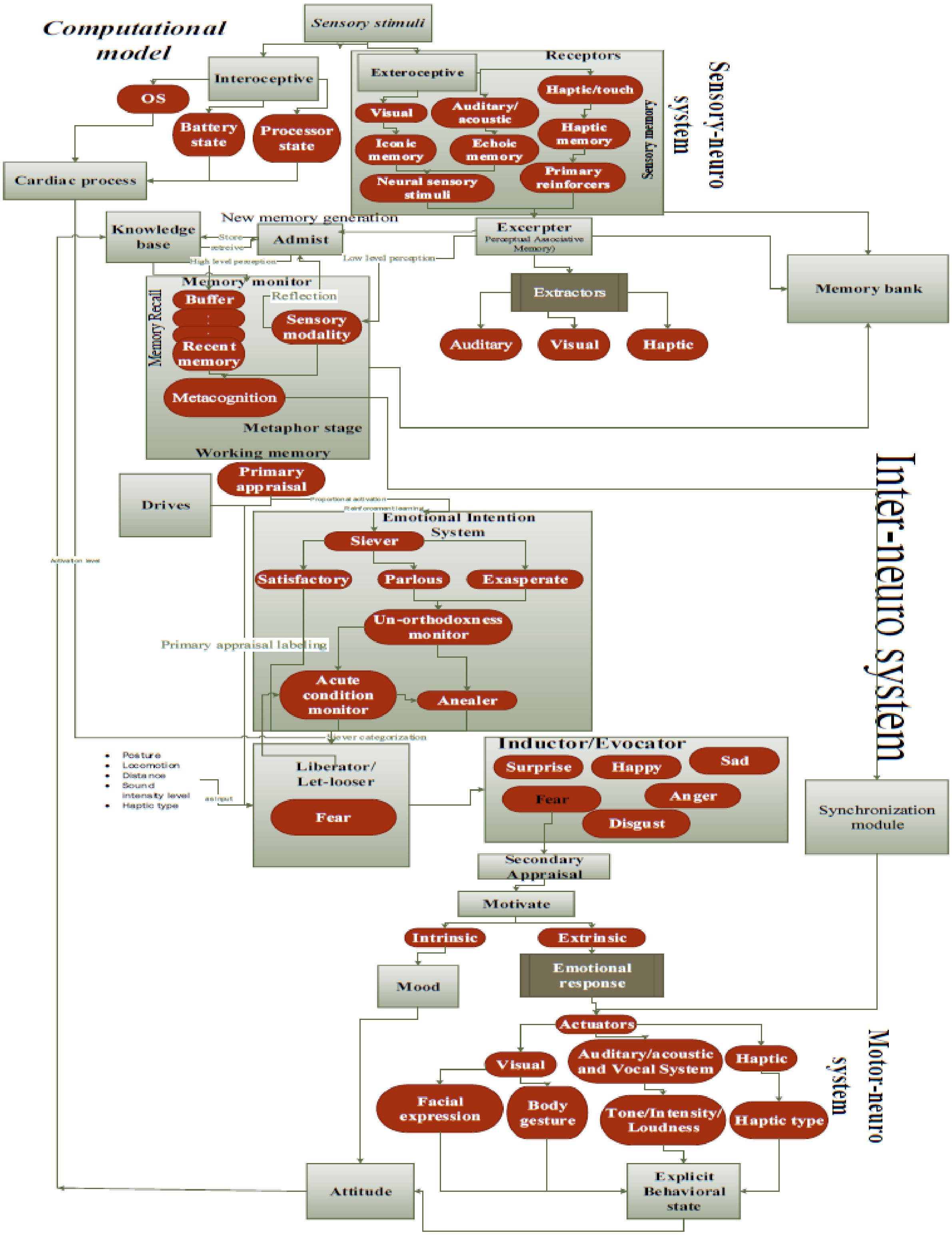

Fig.2. Emotional Intelligence Model

3.5. Neural sensory stimuli

Output from Iconic and echoic memory will use as an input in neural sensory stimulus module. Visual, auditory and haptic stimuli acts as a sensory stimulus. Conversion of stimulus captured through receptors leads to “action potentials” known as “Transduction”. Action potentials are the signals or spikes. These sequential spikes create a “Spike train”. Action potentials acts to excite agent’s sensory organs against the captured Visual and auditory inputs. Its main functionality is to activate inter-neural processes.

3.6. Primary re-enforcers

Emotions closely belongs to primary re-enforcers. Haptic sense is a primary re-enforcer. Visual and auditory are secondary. It greatly affects the intensity of emotional response e.g. Soft touch for agent may exceed happy emotional state (primary emotion) to sincere emotional state (secondary /complex emotion).and hard touch may exceed the level of anger to disgust emotional state.

3.7. Cardiac process

Agent’s cardiac process is based on Battery, processor and Operating System’s state.

3.8. Excerpter

From here, sensory information is send to Excerpter (just like Thalamus, which is part of forebrain especially of limbic system). It realizes and diagnosis (like a doctor) the sensory information. Here acts as a perceptual Associative memory and through extractors, it will extract and categorize [40] the required information from observed stimulus. After that, information will send to other parts for further processing. If this part (module) gets damage, it lacks in processing of sensory information and leads to “sensory confusion”.

3.9. Admist

It assists in the storage of inputs from sensory modalities to long-term memory (based on the working of Hippocampus). It also helps in memory recall (memory retrieval). Any damage in this module may lead to loss of memory or new memory generation as it receives contents from Excerpter and store them to knowledge-base as a new memory.

3.10. Knowledge-base

A centralized repository for explicit knowledge. An “integral component” for storing, optimizing, organizing and management of explicit knowledge. Knowledge base stores the detailed information of that currently perceived sensory stimulus. Here is a need to understand the difference between Data, information and knowledge. Iconic, Echoic and haptic memory just store data. While filtered or extracted data is known as information. Excerpter stores the information extracted through extractors and that information becomes knowledge when it is stored as a LTM in knowledge base in an organized manner for re-usability.

3.11. Memory monitor

Acts as a Working memory(like prefrontal-cortex) .Extracted information through Excerpter generates low-level perception. This information in sensory modality module will generate a reflection to Admist and Admist will retrieve related knowledge from knowledge-base ,if there exists any subjective past experience then it will pass out to Buffer as a recent memory e.g. sensory modality module have complete information including face structure and if there exists any experience regarding that face structure , the whole memory will recall and will be shown in buffer as a memory and both inputs from sensory modality module (currently observed expressions)and from buffer (past expressions) will pass out to meta-cognition module. However, if no experience exists then just sensory modality input will propagate for metaphor stage. This is a self-thinking control stage where emotional detection, organization for emotional reactiveness is done either based on

1. Currently experienced +past experience expressions.

OR

2. Just currently experienced expressions.

Contradiction in both affects activation level. Here agent will be completely conscious about the observed emotional state.

3.12. Drives

An excitatory state or psychological arousal that urge for drive reduction (Known as Homeostasis) by choosing appropriate response against observed expressions. High level primary drives specially “Affiliation and belongingness” essentially for interpersonal contacts for social interaction to form friendship, affiliation or association. Drives through proportional activation (corresponding responsive activation level) generates emotional intention. A sense of feelings will be generated here based on reinforcement learning in a labeled form.

3.13. Emotional-intention system

3.13.1. Siever

For complete gestural emotional response, Manipulator/Rover (agent’s main body) needs to know what type of emotions brain is feeling.

Drive is for correcting the homeostasis disturbance controlled by Siever. Siever is a key to both motivation and emotion. It is called “brain within the brain “It affects different states of emotional responses by physiological changes. Feelings are converted to emotions by siever. Siever is responsible for categorizing the situation state (greatly influence Activation level according to situation). Whether it is ‘ok’, ’Parlous’ or ‘exasperate’ (also based on reinforcement learning).E.g. when walking in dark place, the autonomous response would be to feel anxiety and fear. For appropriate emotional response, siever transmits information to other parts of Rover. It allows the agent for threat detection and run away from it if necessary. Results in agent’s emotional physical response.

3.13.2. Un-Orthodox monitor (UO monitor)

Activities that are not under conscious control are handle by un-orthodox monitor e.g. Parlous and Exasperate. “Molecules of emotions” (hyper/intense emotional reaction spike) are send by subconscious mind through UO monitor (regulated by siever). UO monitor has two branches, both do not work simultaneously. In normal condition, both are synchronized.

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3.13.2.1. Acute condition monitor (AC monitor)

Deals with FEAR, ANGER, DISGUST, SURPRISE situations (like Sympathetic nervous system). These situations are going to be handle under the control of AC monitor results in rapid cardiac process.
AC monitor

1. Control the hyperness.
2. Helps in deciding "Fight or Flight" and "Rest or Digest" (helps in deciding whether to approach or avoid).

3.13.2.2. Annealer

Relax or normalize that hyper condition (based on the working of Parasympathetic nervous system). Normalize the cardiac process. Under the control of AC monitor Anger, Disgust, surprise, fear emotions will be handled by liberator. However, happy and sad emotions will also generate in liberator but based on inputs. Liberator (acts as releasing agent). Energizing level (Activation level) will also calculated by information obtained as input. Based on "How actively respond to that situation?"

3.14. Liberator

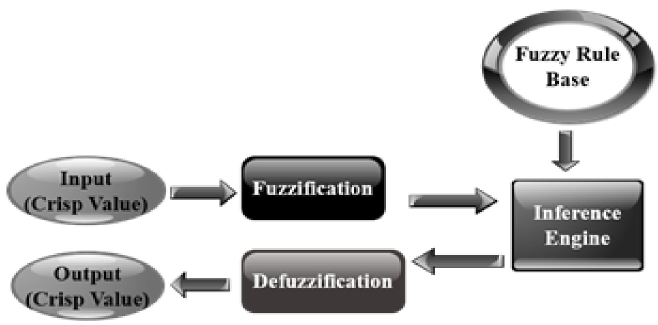

Fig.3. FIS Structure

Emotional state dependence on other factors:

1. Activation level (based on cardiac process).
2. Primary appraisal labeling.
3. Siever categorization.

Other factors e.g. sound intensity level, Haptic type, posture will be help in generating the respectively same response i.e. same intensity level, posture etc. From here, it will pass out to inductor where a specific emotion will evoke among all.

3.15. Evocater

Table 1: Evocater responses

Emotional state	*Reactive action*
Happy	more activation with +ve valence[1]
Sad	less activation with –ve valence
Disgust	Avoid
Anger	Destructive behavior
Fear	Leave, run away
Surprise	Alert generation

[1] Valence can be either positive or negative and observe from" good-ness" or "bad-ness" of expressions or situation.

3.16. Apprasial

Emotional experience's determinants are appraisal. Emotions about a specific situation based on Appraisal.

Emotions are extracted from appraisal (resides between stimulus and emotional response). After evoking specific emotions appraisal is responsible for generation and sustaining of that emotional state. It leads to different emotional responses in different situations. Here labeling of emotional state will be done e.g....' I am afraid', 'I am happy'. Etc. "Two-step appraisal".

3.16.1. Primary appraisal

Evaluate the situation (How significant is it for you? Specifically based on eye contact). Eye contact between interlocutor inforce the agent to respond.

3.16.2. Secondary appraisal

How you are going to respond it by expressions and emotions. Negative appraisal leads to unhappy condition. Positive appraisal leads to satisfied condition.

3.17. Memory Bank

Acts as an operator for all types of memories.

3.18. Synchronization module

For upgrading or synchronizing the actuators against the emotions detected by meta-cognition module.

3.19. Motivation

Secondary appraisal motivates us to express. Motivation is the General inclination to do something, a set of psychological forces that urge to take action. Extrinsic is an external motivation or external incentive that excites agent for emotional response (like interpersonal competency). Intrinsic is internal motivation that helps in generating mood (intra-personal competency). Intrinsic and Extrinsic refers to commencement of emotion. Extrinsic and Intrinsic motivation both assist in driving behavior. A key to changing behavior is motivation. It is an umbrella concept that surrounds both emotions and moods. Motivation directs agent's behavior. It will stimulate/activate/excite the agent's actuators against the emotional state labeled by secondary appraisal.

3.20. Emotional response/intense feelings/Physiological arousal

Feeling's complex state is known as 'emotional response 'express through actuators. It plays an adaptive role.

1. "Experience of perceived expressions".
2. "Externally visible Action".
3. More extreme/Discrete.
4. Naturally, "Action Oriented".
5. Have prominent expressions.
6. Durational brief.
7. Show the Automaticity of agent.
8. Based on reinforcement learning.

3.21. Mood

A cognitive psychological or emotional state. It can be

1. Either good (with +ve valence) or bad (with –ve valence).
2. Long lasting.
3. Have no expressions but greatly influence emotional response.
4. Less intense.
5. Based on activation level

3.22. Explicit-Behavioral state

Chosen and conscious state displaying interpersonally (Socially) and intentionally reported. Emotional response and mood both influence agent's behavior.

3.23. Attitude

"Judgment of perceived expressions". Explicit behavioral state engenders an overall experience, which is put aside to knowledge-base. Personality or idiosyncrasy, which elucidate an agent's overall usual modus operandi to life e.g., "He is always so cheerful". It will store as a recent memory in knowledge-base.

4. SYSTEM VALIDATION AND RESULTS

Liberator ANFIS system is an adaptive neuro fuzzy inference system. Our framework is designed to perceive seven states: Happy, Sad, Disgust, Fear, Surprise, Anger, Neutral. Following are some samples of training, we used 50% data for training ,30% data for checking and 20% data for testing.

4.1. Input Parameters [41-42]

Characterization for the five input factors subsequently:

1. Voice_pitch: [20;15000] in HZ
2. Voice_intensity [0;90] in db
3. Eye_fold: [-100; 40]
4. Face: [-100; 10]
5. Monobrow: [-100; 100]

The fuzzy sets of input parameters Eye_fold, face, and monobrow are: small, medium and high, for the Voice_pitch are: too_much_lower, slightly_lower, slightly_higher, too_much_higher and for the Voice_intensity are: whisper, normal,too_loud.

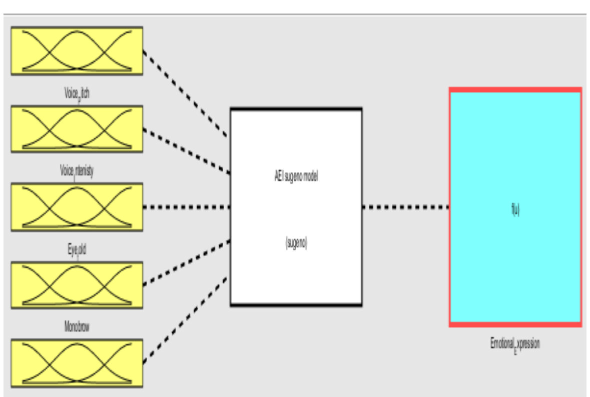

Fig .4. ANFIS Model

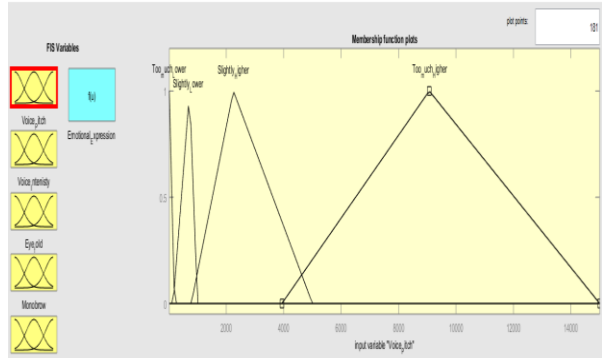

Fig.5. Voice pitch Member Functions

Table 2: Agent's Training

Voice pitch	Voice Intensity	Eyelid	Eyebrow	Mouth	Emotion
-1	-1	-99	2	-60	0.1
1000	1000	0	-20	-100	0.3
1000	1000	20	-80	-40	0.9
1000	1000	-10	50	10	0.5
1000	1000	20	60	-50	0.7
1000	1000	30	-50	-80	1.1
1000	-1000	10	-30	-90	1.3
1000	-1000	-70	-10	-55	0
10000	-1000	25	-15	-70	0.2
1000	-1000	35	-75	-55	0.8
1000	-1000	35	9	70	0.4
1000	-1000	35	85	-50	0.6
1000	-1000	-14	-56	-70	1
10000	-10000	-25	-35	-95	1.2
4000	60	-500	-4000	-1000	1
800	65	-1000	-4000	-1000	0.1
500	20	-1000	-1000	-1000	0.3
12000	40	-2000	-50000	-1000	0.7
150	14	-2000	-6000	-1000	1.1
11000	75	-3000	-1000	-1000	0.9
850	69	-3000	-1000	-1000	0
450	9	-4000	-1000	-1000	0.2
14000	45	-1000	-1000	-1000	0.7
90	8	-1000	-1000	-1000	1.1

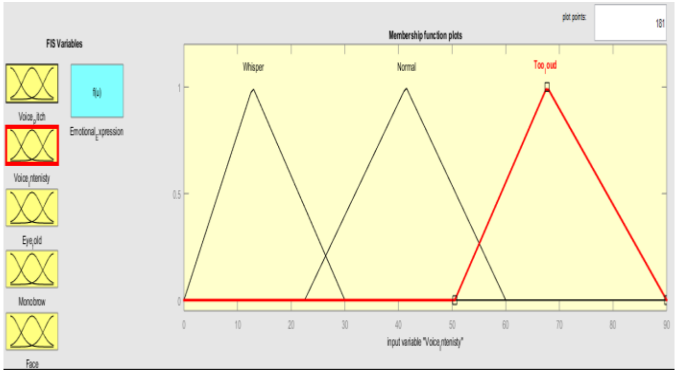

Fig.6. Voice Intensity member function

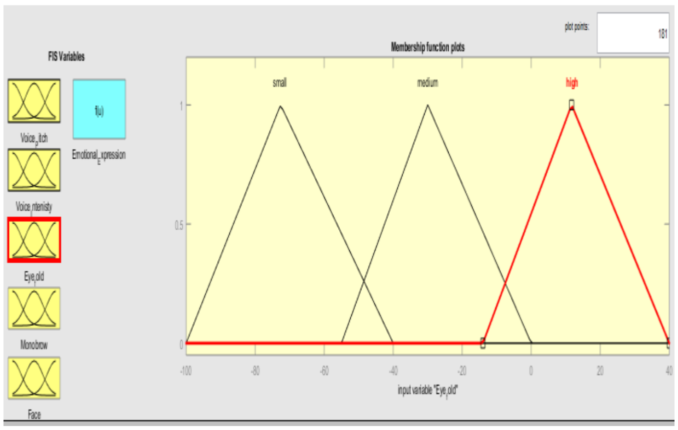

Fig.7. Eye_fold Member functions

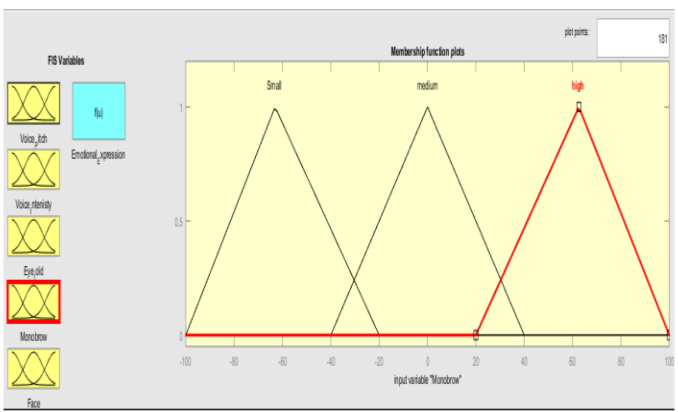

Fig.8. Monobrow member functions

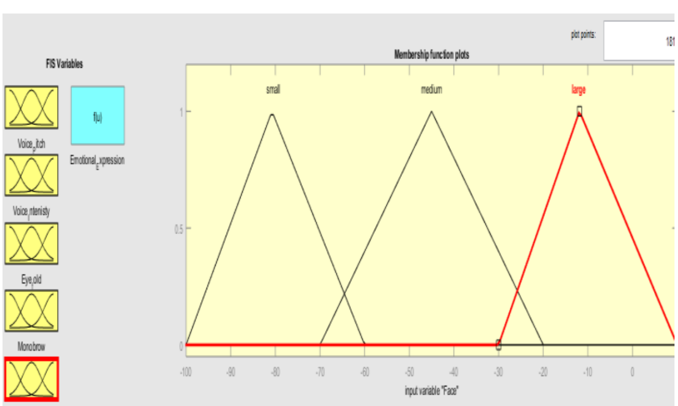

Fig.9. Face Member Functions

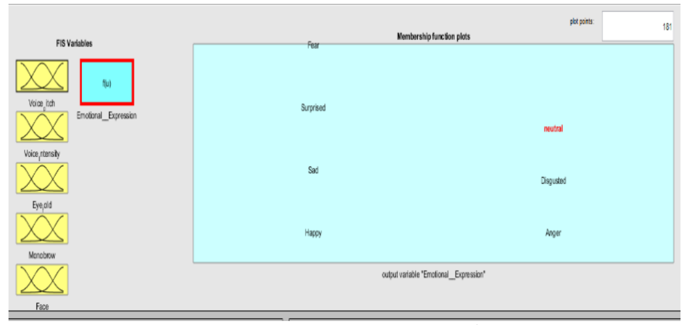

Fig.10. Emotional expression member functions

4.2. Output Parameters [41-42]

For the yield parameter Emotional Expression, the specified range is [0;1.4] , their corresponding fuzzy sets are: happy[0;0.2], sad[0.2;0.4], surprised [0.4;0.6], fear[0.6;0.8], anger[0.8;1], disgusted[1;1.2], and neutral[1.2;1.4].

4.3. Fuzzy rules

The framework works with rules i.e. If, Then type Fuzzy rules. That exhibit the framework to be automated. It constitutes a Fuzzy rule base for the framework with different fuzzy rules.

1. If (Voice_pitch is too_much_higher) and (Voice_intensity is Too_loud) then (Emotional is Anger);
2. If (voice_pitch is slightly_higher) and (voice_intensity is too_loud) then (Emotion is happy);
3. If (voice_pitch is slightly_higher) and (voice_intensity is whisper) then (Emotion is sad);
4. If (voice_pitch is too_much_higher) and (voice_intensity is normal) then (Emotion is fear);
5. If (voice_pitch is too much _higher) and (voice_intensity is whisper) then (Emotion is disgust);
6. If (the face is medium) and (Eye_fold is small) and (monobrow is medium) then (Emotion_Expression is happy);
7. If (face is small) and (Eye_fold is high) and (monobrow is medium) then (Emotion_Expression_ is sad);
8. If (face is large) and (Eye_fold is high) and (monobrow is high) then (Emotional_Expression is surprised);
9. If (face is medium) and (Eye_fold is high) and (monobrow is high) then (Emotional_Expression is fear);
10. If (face is medium) and (Eye_fold is high) and (monbrow is small) then (Emotional_Expression is anger);
11. If (face is small) and (Eye_fold is medium) and (Monobrow is small) then (Emotional_Expression is disgust);
12. If (face is small) and (Eye_fold is medium) and (Monobrow is medium) then (Emotional_Expression is neutral);[41]

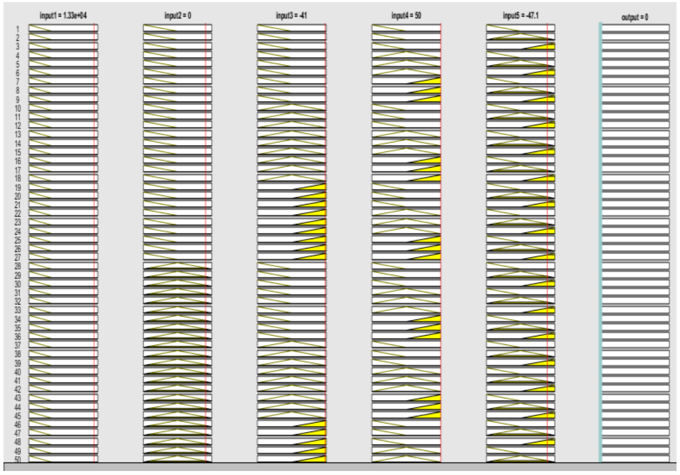

Fig.11. Fuzzy Rules (Resulted design)

4.4. Structure of AEI Sugeno model

There are five distinct layers in this sugeno model framework: the primary layer represents the information factors (Voice_pitch, Voice_intensity, monobrow, eye_fold, face), second one is the participation elements of sources of information that are the sort trimf; the third layer is the rules framework (Fuzzy Rules); Emotional_Expression (seven) is shown by fourth layer, and consequently the output is shown by fifth layer.

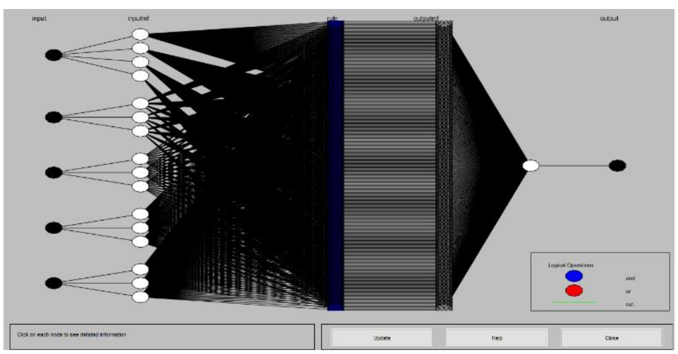

Fig.12. AEI ANFIS Structure (Proposed)

We have accomplished the best outcomes for the training of artificial neuro-fuzzy inference system using membership function trimf. The outcomes are shown for each input parameter to Fig. 11.

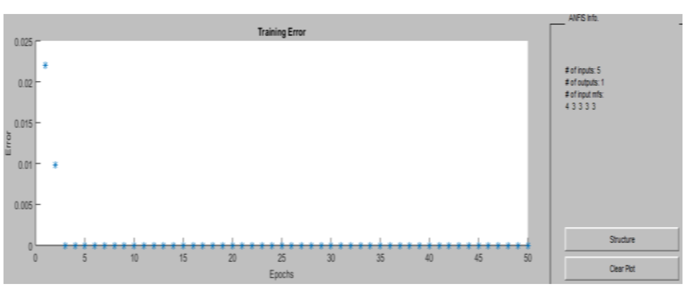

Fig.13. Training of data

5. DISCUSSION

We proposed a neuro fuzzy model of human emotion recognition utilizing five elements of the human traits that can make a major difference in the categorization of the emotional expressions. Through the training of “artificial neuro-fuzzy inference (ANFIS)” framework utilizing trimf. function, best results are achieved. The outcomes are shown for each input parameter. Our proposed System as a future work can be extended to recognize secondary emotions.

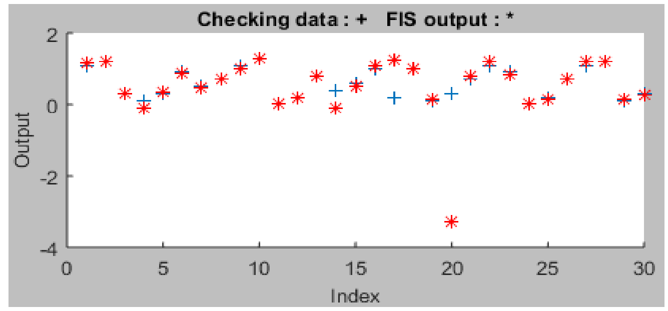

Fig.14. Checking

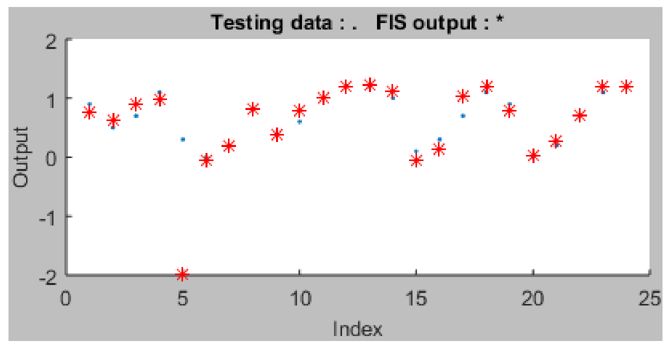

Fig.15. Testing

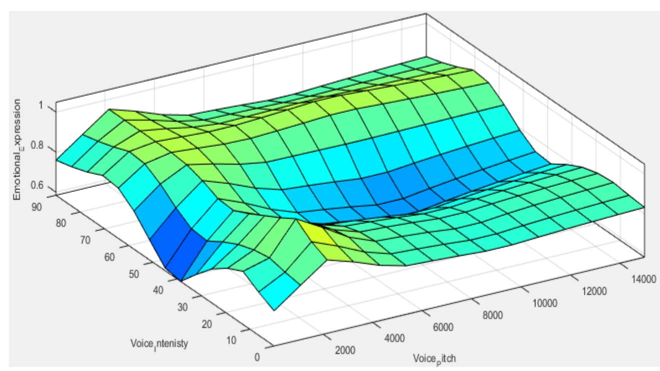

Fig.16. Surface Viewer

6. CONCLUSION

To regulate sense of social interaction between human and robot’s emotional intelligence play a key role. To have an understanding about human’s emotional state and respond accordingly will help in creating a natural interaction without any realization of human-machine interaction. This paper proposes a “Neuro-biological model for emotional intelligence in Humanoid robots” for creating the sense of emotional interaction and affiliation in humanoid.

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