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CONTENTS

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:

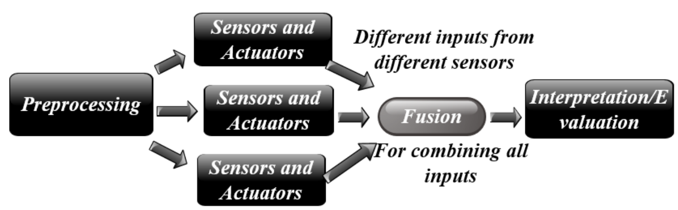

Fig.1. Processing

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).

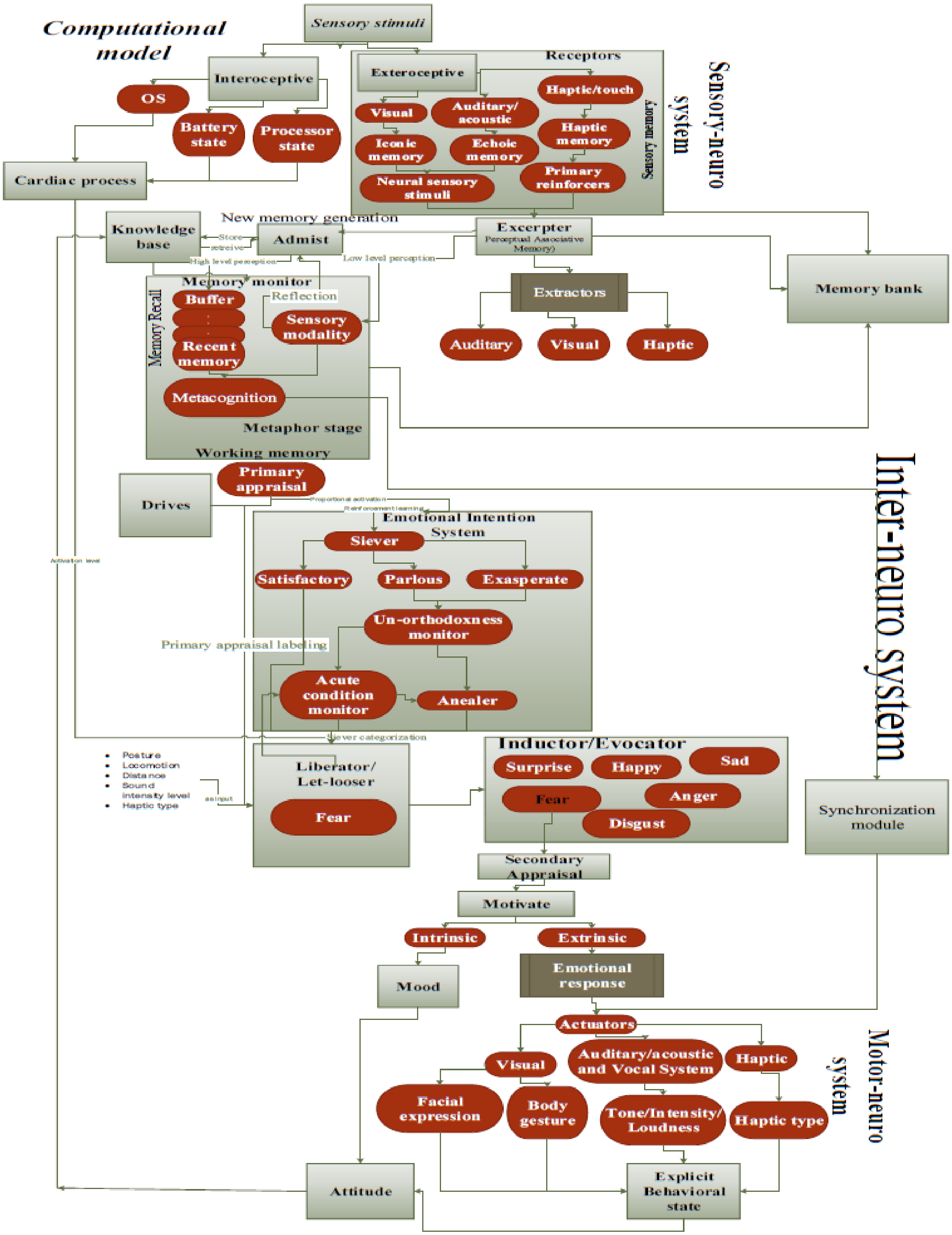

Fig.2. Emotional Intelligence Model

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.

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

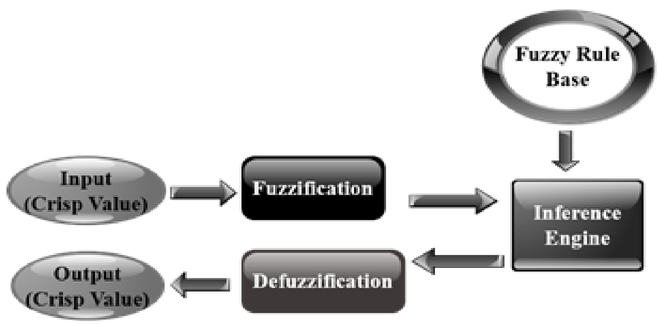

Fig.3. FIS Structure

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.

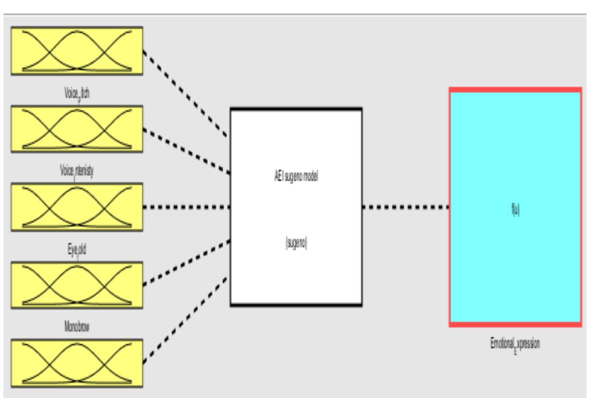

Fig .4. ANFIS Model

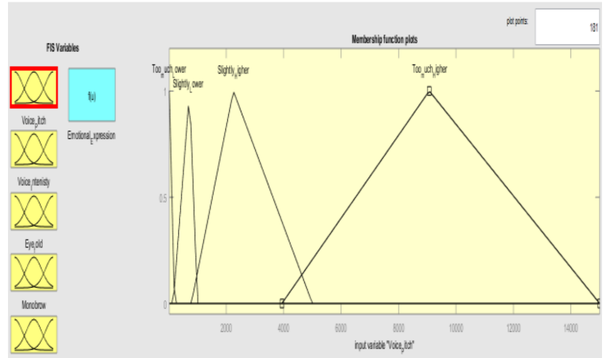

Fig.5. Voice pitch Member Functions

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

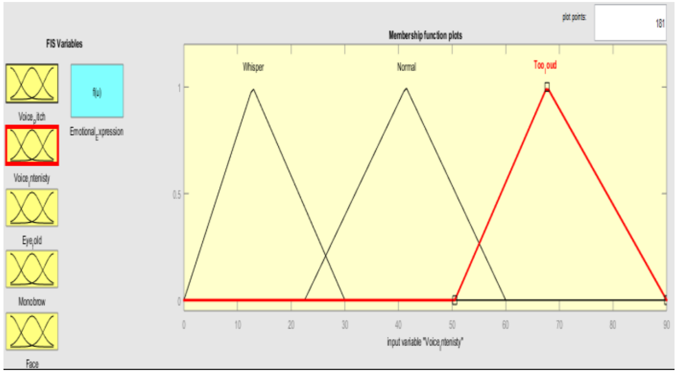

Fig.6. Voice Intensity member function

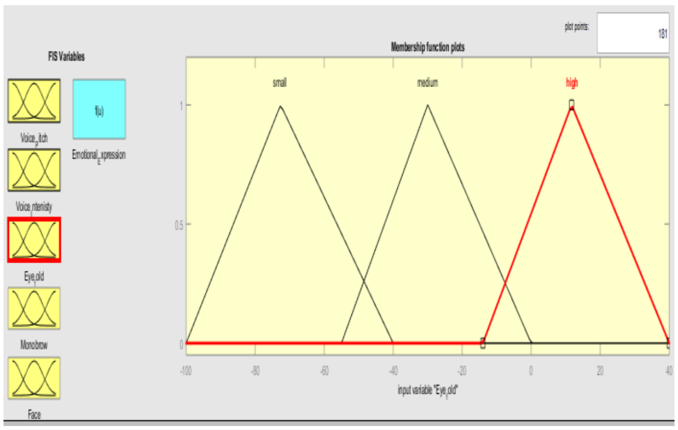

Fig.7. Eye_fold Member functions

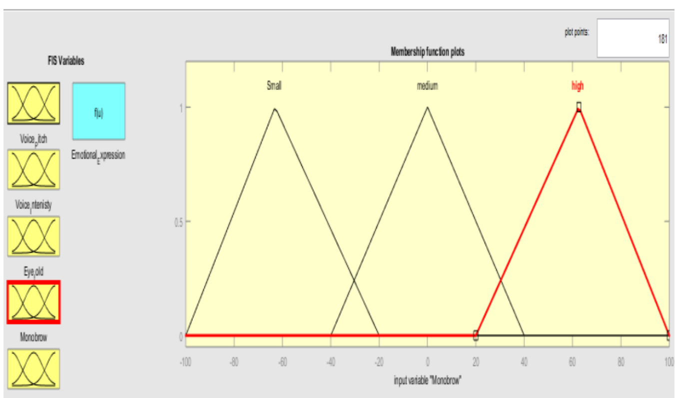

Fig.8. Monobrow member functions

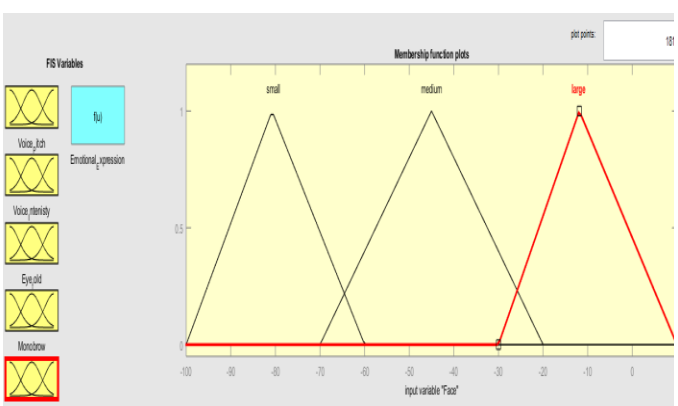

Fig.9. Face Member Functions

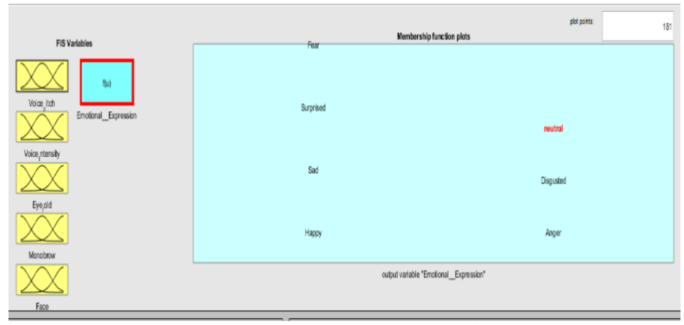

Fig.10. Emotional expression member functions

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]

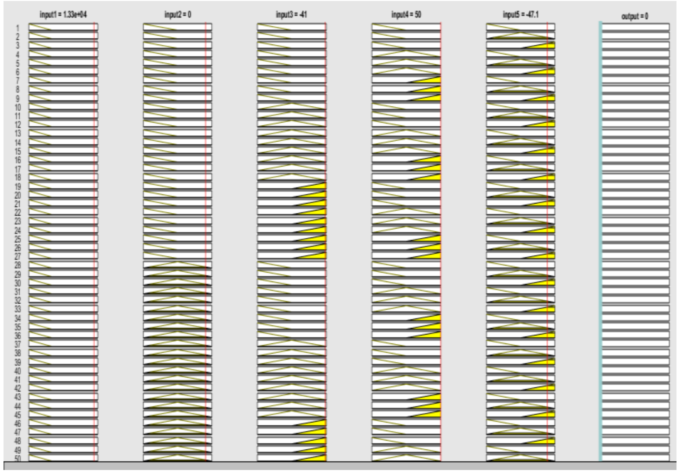

Fig.11. Fuzzy Rules (Resulted design)

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.

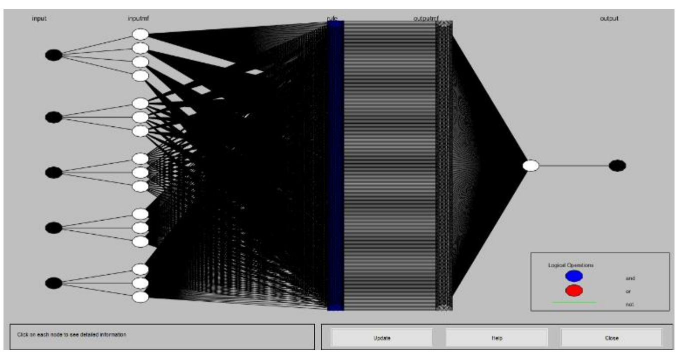

Fig.12. AEI ANFIS Structure (Proposed)

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.

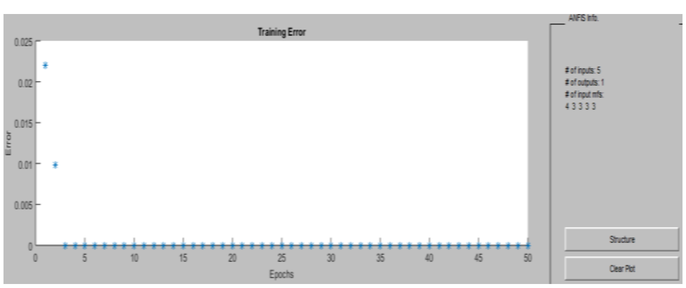

Fig.13. Training of data

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.

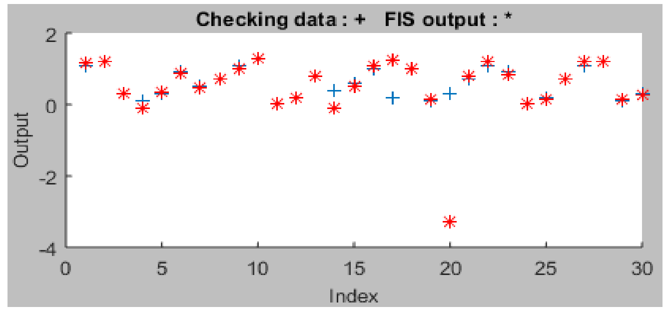

Fig.14. Checking

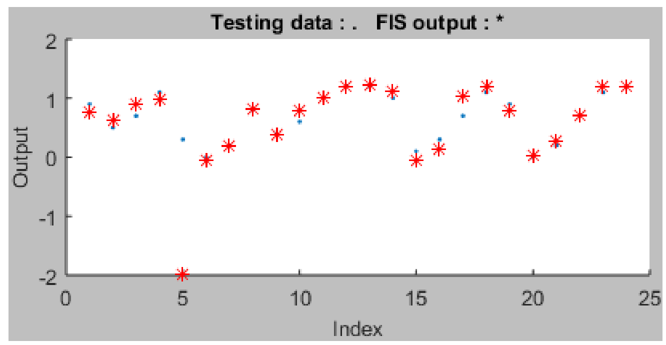

Fig.15. Testing

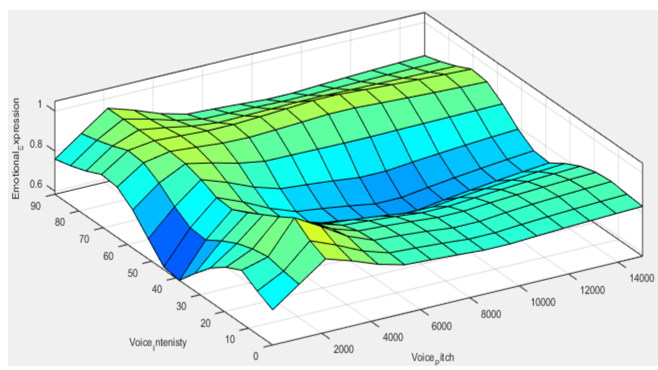

Fig.16. Surface Viewer

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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COGNITIVE METHODS IN TECHNOLOGIES OF CREATING COMPUTER GAMES

J. Breslavets, V. Breslavets, O. Kasilov and O. Serkov

Abstract— The use of computer training systems allows individuals to individualize the learning process for each student on the basis of information technology. The purpose of the work is to control the behavior of the student by changing the objective complexity of the teaching material in accordance with the subjective complexity that arises during the training. The task is to develop and theoretical substantiation of the methods of the individualized approach of students for training professional competencies by creating individual trajectories for the seizure and acquisition of knowledge on the basis of information technologies. The method of organizing the learning process with the use of a computer training system, the functioning of which is implemented by a person-oriented student model, is formed. The results of the experimental study proved that due to the adaptation, each student begins to work with the same intellectual load for different categories of students. The structuring of didactic material in the form of a graph with vertices of the corresponding sections of the content, and the management of transitions implements the control system of mastering the material, allows to improve the process of individualization of training.

Keywords— *Individualization of Training; Computer Training System; Person-Oriented Learning.*

1. INTRODUCTION

THE global informatization of comprehensive human activity is the dominant trend in the development of the modern world. In this regard, informatization of education is the most important direction of the implementation of the modern educational paradigm. Application of modern intellectual technologies allows qualitatively changing the didactic process and individualizing the learning process. Moreover, under individualized training, we understand learning based on the individual characteristics of a person, which allows creating the optimal conditions for the best development of the person, the formation of his ability to implement in various fields of activity.

The introduction of modern intelligent information technologies allows a new approach to the problem of individualization of education. The use of computer didactics based on the principles of artificial intelligence allows the implementation of the ideas of personalized learning. In turn, this allows improving the quality of education and promotes the development of professional competencies of the individual. With the use of intelligent information technology, it becomes possible to differentiate educational material according to different parameters. In addition, while defining the characteristics of the student, it is possible to build individual trajectories of learning, taking into account the dynamics and the possibility of changing the trajectory of learning, adapting to its individual characteristics. This allows for the creation of parametric student models that reflect the peculiarities of its cognitive development, in particular, the level of learning and the dynamics of learning. In particular, the created model allows predicting the optimal trajectories of training for a particular individual, modeling various educational situations, which reveals not only the learning process, but also the process of personality development.

Implementation of this approach requires the creation of computer intellectual didactic systems that would allow to predict individual trajectories of learning and to implement, in accordance with them, the educational process. Moreover, individualized learning and a person-oriented approach expand the didactic capabilities of computer learning tools.

2. THE PURPOSE AND TASKS OF THE PUBLICATION

The purpose of the work is to manage student behavior by changing the objective complexity of the teaching material in accordance with the subjective complexity that arises during its study. The purpose of this publication is to develop and theoretical substantiation of the methods of the individualized approach of students to the training of professional competencies by creating individual trajectories for the seizure and acquisition of knowledge on the basis of information technologies.

3. FORMULATION OF THE PROBLEM

In an automated learning system, the object of control is a student who learns certain knowledge. As with any control system, it is possible to highlight two streams of information - direct and inverse. The direct flow of information, or direct influences, brings the learning information of the control object. The reverse flow characterizes the changes that arise at the level of the student's knowledge and is analyzed by the system that teaches them. In this case, there is no doubt that the main way to improve the effectiveness of learning is to improve

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direct influences. This is due to the fact that due to only direct influences the learning process takes place.

4. BRAIN MODEL

One way to manage a learner's activity while learning a course material is to change the level of accessibility of the content provided by the student. This is because the same content can be described with different levels of accessibility, which causes a different level of difficulty when it is studied by the student. At the present stage of the development of information technologies, it is practically impossible to synthesize arbitrary text with the given accessibility of presentation. It is also impossible to do this synthesis during real-time learning. Thus, preliminary development of educational content is required, which is differentiated by complexity.

The question of analyzing the complexity of various educational material and the possibility of its differentiation by complexity is partially considered in the work of Sokhor A.M. [1], in which the author considers the features of the definition of the logical structure of the educational material. In this case, the complexity of the educational material is measured by some objective characteristics. However, during an individual work on content, there are complexities of assimilation, which are completely dependent on the subject. Subjective difficulty mastering information while working on the content, perhaps measured by indicators such as the number of errors that made the students while performing tests of control and rate [2.3].

In this case, the object of control is the student, and the controlled process is the process of mastering the knowledge of this student. At the initial moment of study, the course of the assimilation process of the initial material is usually not defined. Characteristics of this process cannot be pre-determined experimentally. Thus the ability to control objects with a high degree of uncertainty based on the initial use of adaptation when the initial uncertainty is reduced through the use of the information obtained in the learning process.

However, in educational systems, adaptation cannot be fully exploited. This is hindered by the following. First, the feedback information does not allow to effectively evaluate the student's mental processes during training. It is only possible with a certain probability to estimate how the acquired knowledge is acquired. Secondly, even evaluating the process of assimilation is sufficiently reliably impossible to effectively influence its changes because the system of managing influences was created in advance without taking into account the individual characteristics of the student.

These restrictions are valid for learning knowledge and lose meaning when learning skills [4].

5. DEVELOPMENT OF THE DIDACTIC SYSTEM

In Fig. 1 shows the structure of the educational system that implements these principles [5]. Some training object is present in the source of educational information in the form of a plurality of portions of the material, which comprise the text and control questions. The figure depicts the interaction of blocks and shaded concepts that are covered by control issues. According to the results of work on the previous doses of content determined by some i – the level of objective complexity of the material. The student is provided with a portion that includes the text Ti and the set of control questions {Ki}. The Answering Block analyzes student responses.

The assessment of responses is based on the principle of determining the percentage of correct answers or not. And with the help of the block of determination of the pace of work, comparing the work time with the teaching material with the permissible time norm. The results of this comparison also make a decision whether or not. Information from these blocks comes to memory, where information about the results of the performance of the last three control tasks is stored. It allows you to evaluate the subjective difficulties that cause the content over which the student works. According to the results of analysis and in accordance with the learning algorithm, the level of complexity of the new material is selected.

The proposed method for constructing the didactic system of person-oriented learning was implemented and passed an experimental test [5]. During the experiment, an educational program with three levels of difficulty, as well as various means of correction of errors [6] was studied. There were two ways to correct errors. In the first method, the student himself found the reason for the false answer, studying the same material, but in a more detailed presentation. Another way was to get the student a full explanation of what the correct answer should be. Figure 2 shows the change in the average work time over the dose of the training material (dependence of 1,2) and the percentage of correct answers to the control questions of one dose of the material (dependence of 3.4) for the group of students. Dependencies 2, 4 correspond to the second method of correction of errors, depending on 1, 3 - the first. According to the results of the analysis of the above graphic materials, one can conclude that the second way of correction of errors, unlike the first, reduces the student's activity to the end of work on content. This is due to reduced working time on one dose of material and an increased number of errors.

The results of the experiment proved that adapting to the individual characteristics of the student led to the fact that each of them began to work on accessible material. There was no significant difference in time in this case, which could be interpreted as roughly the same intellectual load. for different categories of students. At the same time, the clear structuring of the didactic material in the form of a graph in which the vertices correspond to the sections of the material, and transition management is implemented using a test system for assimilating the material of the unit, which allows for the full implementation of personalized learning.

Implementation of the developed approach clearly demonstrates the process of the motivation of students during training with the use of computer gaming technologies. So the availability of multiple levels of difficulty allows people with different skills to participate in the game and move to higher levels after sufficient practice and become an expert. Granting access at different difficulty levels means that not all students are on the same trajectory. Playing at the most appropriate level of difficulty not only helps the player interested in playing, but also in terms of experience, preparing for the transition to the next, higher level of difficulty. The requirements of the game vary from one moment to the next, from the situation to the

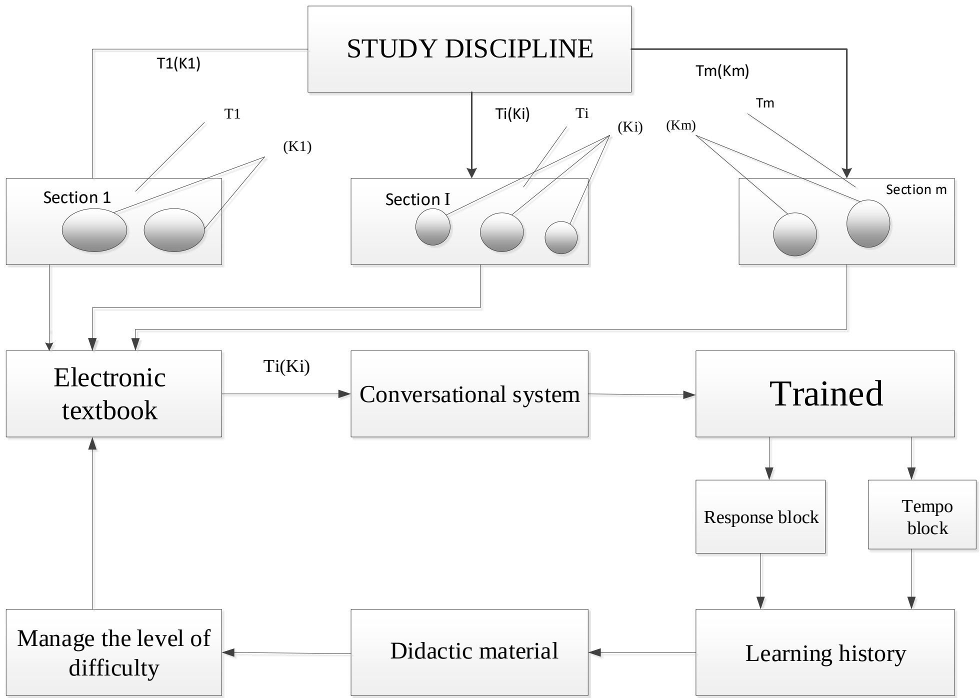

Figure1 - The structure of the didactic system of person-oriented learning

situation. This creates a problem in assessing which cognitive functions have been active and for how long.

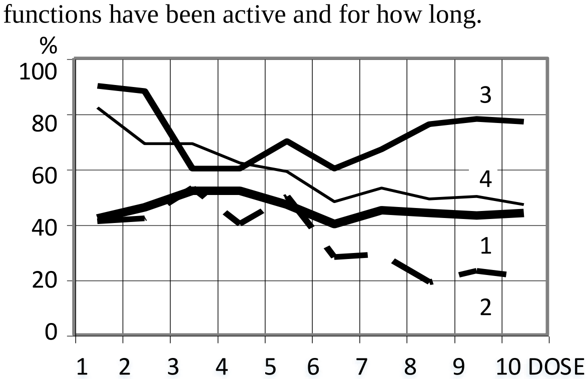

Figure 2 – Average working time on the dose and percentage of correct answers: 1 - time with correction of errors in a 1st way; 2 - time with correction of errors in a 2nd way; 3 –a percentage of correct answers with correction of errors in a first way; 4 – a percentage of correct answers with correction of errors in the second method.

The development of computer gaming technologies has shown that the main way to improve the effectiveness of training is to improve the direct effects channels, in particular, the use of the 3-dimensional visualized environment. This is due to the fact that the human perception system was developed in a three-dimensional space. Therefore, the initial sensory processing of the visual environment is carried out with a reflection of what we see in the real environment. Considering that several visual events may occur practically simultaneously in different places of gambling space, the main priority of the player is to quickly locate, identify and assess the level of potential threats to the player. To do this, an effective scanning of the visual space should be performed.

Computer gaming environments are very complex. The complexity of the task depends on the content and such fundamental features as spatial selective attention, memory and other sensory and perceptual abilities. It requires, besides basic operations, additional cognitive processes, such as search, comparison,a symbolic solution to a problem.

Usually, players take part in several simultaneous events. Many cognitive and motor skills are involved. Simultaneous tracking of multiple objects, visiting multiple places in the gambling space or solving more than two tasks simultaneously requires the allocation of attention. In turn, the allocation of attention reduces the speed and correctness of the decisions taken by the player. This imposes restrictions on the number of objects, their location and the number of tasks that need to be solved simultaneously. Normally, a person can not simultaneously hold more than 4 elements in the RAM and visit more than 4 objects at a time. Memory allows you to store, maintain and subsequently remove information. Distinguish operative and long-term memory. RAM stores information for current manipulation and is closely related to the system of attention. Instead, long-term memory gets information through the learning process and vice versa. RAM gets information from a long-term storage site in accordance with the requirements of the current task and under the control of executive processes in the human brain. In this way, operational and long-term memory complement each other. The inability to efficiently store and process information in the RAM leads to low performance in solving many problems.

The spatial focus execution processes track the contents of the RAM and coordinate other brain systems that are needed to service and select features of the objects.

Effective work of spatial selective attention and memory is important for solving complex spatial problems.

In addition to focusing attention, there is often a need to switch attention from one location to an object or a task to another. Such switching also involves the cost of processing information as it takes some time to unlock and re-launch. The quick switching of attention from the current task to the new requires additional time losses, especially for beginners.

On the other hand, the proliferation of attention on a wide field of view allows you to see the peripheral world without concentrating attention on most objects of the periphery. However, the visual system can not handle all the information. Most of the raw visual information is not important for the purpose of the game and can be ignored.

At the same time, in order to attract attention and reduce the processing time of the information, the visual system should be sensitive to changing the position of the object, brightness, and color. Attention is directed directly to the place where the sudden change occurred, which is associated with a sudden start or a change that attracts attention. Sudden events are quickly analyzed by the brain, using processes that require identification, recognition, and decision making. Usually, processes pass through the eyes and moves. The next step is to recognize the object that attracted attention by rejecting information that is not related to the object. This is visual selective attention. Gram practice improves the ability of spatial selective attention. Thus, improving this basic skill increases the productivity of other tasks by maintaining functions that depend on this ability.

6. CONCLUSIONS

New methods of cognitive learning, based on video games, help develop, preserve and improve spatial cognition. All tasks in spatial cognition are supported by attention and level of RAM, which are closely interconnected. Complex spatial tasks require quick removal, decoupling and redistribution of attention for the multitude of features of the object. At the same time during several stages of processing information should selectively switch the attention between the qualities of the object in the memory to support their activity.

The method of organizing the learning process with the use of a computer training system, the functioning of which is implemented by a person-oriented student model, is formed. The results of the experimental study proved that due to the adaptation, each student begins to work with the same intellectual load for different categories of students. The structuring of the didactic material in the form of a graph whose vertices are the corresponding sections of the content, and the transition management implements the control system for mastering the material, enables to improve the process of individualization of education

The large amount of information that requires processing in spatial cognition provides the opportunity to use visual information to control the motor system while performing tasks. It is determined that visual coordinate coordination is the main skill for implementing an adequate reaction to changing the external environment in computer games.

Thus, the cognitive techniques used in the development of computer games can revolutionize the teaching of spatial skills and concepts. In turn, this will have significant social and economic implications in the field of basic education.

Further research should also be directed in the direction of identifying the regularities of the process of learning knowledge through learning by controlling the student's attention with the use of neural interfaces.

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THE EFFECT OF KERNEL VALUES IN SUPPORT VECTOR MACHINE TO FORECASTING PERFORMANCE OF FINANCIAL TIME SERIES AND COGNITIVE DECISION MAKING

A. Altan and S. Karasu

Abstract— Nowadays, one of the most important research topics in economic sciences is the estimation of different financial exchange rates. The reliable and accurate forecasting of the exchange rate in the financial markets is of great importance, particularly after the recent global economic crises. In addition, the high accuracy forecasting of the financial exchange rates causes that investors are less affected by financial bubbles and crashes. In this paper, a financial time series forecasting model is identified by support vector machine (SVM), which is one of the machine learning methods, for estimating the closing price of USD/TRY and EUR/TRY exchange rates. The closing price values and commodity channel index (CCI) indicator value are used as inputs in financial time series forecasting model. Various models are obtained with different kernel scale values in SVM and the model that estimates financial time series with the highest accuracy is proposed. The performance of the obtained models is measured by means of Pearson correlation and statistical indicators such as mean absolute error (MAE), mean squared error (MSE), and root mean squared error (RMSE). It is seen that the forecasting performance of the proposed SVM model for the financial time series data set is higher than that the performance of the compared other models. The proposed model will provide a positive contribution to the cognitive decision-making process of investors.

Keywords— *Financial Time Series, Support Vector Machine, Kernel Scale, Exchange Rate Forecasting, Cognitive Process, Machine Learning.*

1. INTRODUCTION

IN the last decade, financial markets have often faced bubbles and crashes due to global economic crises. The forecasting of different financial indices based on time series allows investors to act more consciously against these bubbles and crashes in financial markets [1]. In the financial markets where there has been serious competition for many years, many different forecasting models have been developed by financial regulators, policy makers, risk and portfolio managers, financial institutions and investors to be one step ahead of the market or to explain the reason of price changes [2]. In this study, the exchange rate is estimated for different kernel scale values in support vector machine (SVM) which is one of the methods of machine learning by using time series consisting of closing prices of USD/TRY and EUR/TRY exchange rates.

In [3], the exchange rate estimation is performed by using the USD/TRY exchange rate data with Grey-Markov method. It is stated that the performance of the model is good for a short-term period but the performance of the model decreased as the estimation horizon is extended. It is expressed that the proposed model is highly dependent on the range distribution, and the number of cases in the Markov chain can be increased by increasing the forecasting accuracy of the model. Also, it is emphasized that the effect of volatility is reduced by the proposed model. In [4], a new hybrid artificial neural network (ANN) and autoregressive integrated moving average (ARIMA) model is proposed as an alternative forecasting technique to the traditional hybrid ARIMA/ANNs models for time series forecasting. It is highlighted that the proposed model captures different forms of relationship in time series data, especially in complex problems with both linear and nonlinear correlation structures. It is guaranteed that the performance of the proposed model is not be worse than the single ANN and ARIMA components used. In [5], a methodology is presented that using *k*-nearest neighbors (KNN) with dynamic time warping as distance function in a particular procedure to improve the directional status estimation results. It is pointed out that the study conducted with the USD/JPY exchange rate time series has improved the prediction regarding the direction of time series. In [6], exchange rates such as EUR/USD, GBP/USD and USD/JPY are estimated for daily, monthly and quarterly steps with ANN. It has been shown that the proposed short-term forecasting method has good predictive performance and can be used in practical systems to estimate the exchange rate for one step ahead. In [7], the relationship between the exchange rate of USD/TRY, gold prices and the Borsa Istanbul (BIST) 100 index has been estimated by using the ANN method and the method of Vector Autoregressive (VAR). The estimation results obtained by ANN and VAR are compared and it is indicated that ANN is more accurate than VAR. In [8], the performance of ARIMA, ANN and neuro fuzzy models have been investigated in the estimation of currencies traded in Indian currency markets. In [9], self-excited threshold autoregressive (SETAR) models have been used in order to be able to model the volatile changes in currency market. The linearity of the exchange rates, which are dealt with before the SETAR modelling approach is applied, have been examined with the help of various approaches such as Tsay, Keenan, Likelihood Ratio. In [10], the exchange rates of EUR/USD, GBP/USD and USD/JPY have been estimated by the multi-layer perceptron (MLP) neural network. The gold price has been used as an input to the MLP neural network. The fact that the use of gold as an external factor has been improved the exchange rate forecasting. In [11], the forex prediction model based on support vector regression (SVR) machine has been developed, taking the radial basis function as a kernel function.

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2. Human Behavior and Cognition

The optimization of model parameters, including penalty factor and kernel function variance, has been performed by artificial fish swarm algorithm. The performance of the proposed model has been tested for nine exchange rate data with updated and rolling. In [12], Bitcoin (BTC) prediction is performed by linear regression and SVM by using time series consisting of daily BTC closing prices.

Decision making is one of the basic cognitive processes of human behavior based on specific criteria. These cognitive processes are defined as a preferred option or an action from among a set of alternatives [13]. In this study, the financial time series forecasting model which has high performance is proposed that will contribute positively to investors' cognitive decision making process.

The purpose of this study is to test the effect of the kernel values in SVM model on the forecasting performance of USD/TRY and EUR/TRY exchange rates so that investors can use them as technical analysis methods. The rest of the paper is organized as follows. The SVM models used for forecasting are described in Section 3. The experimental procedure and forecasting results are presented in Section 4. Finally, the conclusions are highlighted in Section 5.

3. Forecasting Model

In this study, financial time series data sets, which include the closing prices of USD/TRY and EUR/TRY exchange rates, are used. The financial time series containing daily closing prices have been included data between 01 June 2010 and 11 May 2019 for the USD/TRY and between 21 September 2011 and 14 May 2019 for the EUR/TRY. The graphics of closing price for USD/TRY and EUR/TRY exchange rates are presented in Fig. 1. The minimum value, maximum value, mean value and standard deviation of the USD/TRY and EUR/TRY exchange rates for the data set used are given in Table 1 and 2, respectively. The number of samples used in this study is 2593 for USD/TRY data set and 2049 for EUR/TRY data set. Each data set is divided into three sets as training, validation and test. 10-fold cross validation method is used in the model training stage.

3.1. Filtering Process

For a filter with the length N and the filter coefficient w, the filtering is carried out with the aid of the

$$y_n^+ = \frac{\sum_{i=1}^{N} w_i y_i}{\sum_{i=1}^{N} w_i} \tag{1}$$

filtered value from the dependent variable y. The w coefficients for the weighted moving average (WMA) filter are determined as

$$w_i = i \quad \text{for} \quad i \leq N \tag{2}$$

For the selected length on the signal in the WMA filter, linearly decreasing weight values that is from the nearest value of the filtered signal to the previous value are used [14].

3.2. Commodity Channel Index

The commodity channel index (CCI) is a momentum-based oscillator used to help determine when an investment vehicle is reaching a condition of being overbought or oversold. The CCI is an oscillator, which is unbounded in fluctuation. Its value is different without limits. The CCI measures the current price level relative to an average price level over a given period of time. It is also used to assess price trend direction and strength. This information allows traders to determine if they want to enter or exit a trade, refrain from taking a trade, or add to an existing position. In this way, the indicator can be used to provide trade signals when it acts in a certain way. The calculation of CCI is [15].

$$\text{CCI} = \frac{X_T - \overline{X}}{0.015 \times Mean\ Deviation} \tag{3}$$

where X_T is typical price, $\overline{X}$ is moving average, M is the number of days in data base and X_M is the oldest typical price in data base. X_T, $\overline{X}$, and mean deviation is defined as

$$X_T = (High + Low + Close)/3 \tag{4}$$

$$\overline{X} = \frac{1}{M}\sum_{j=1}^{M} X_j \tag{5}$$

$$Mean\ Deviation = \frac{1}{M}\sum_{j=1}^{M} \left| X_j - \overline{X} \right| \tag{6}$$

TABLE I
STATISTICAL VALUES OF USD/TRY

Years	***Min***	***Max***	***Mean***	***Std***
2010	1.3941	1.6012	1.5020	0.0529
2011	1.5092	1.9170	1.6846	0.1242
2012	1.7425	1.8902	1.7988	0.0267
2013	1.7473	2.1526	1.9040	0.1066
2014	2.0677	2.3693	2.1900	0.0673
2015	2.2809	3.0572	2.7242	0.1972
2016	2.7953	3.5352	3.0247	0.1895
2017	3.4003	3.9652	3.6440	0.1366
2018	3.7293	6.9724	4.8415	0.8720
2019	5.1784	6.1938	5.5197	0.2594

TABLE II
STATISTICAL VALUES OF EUR/TRY

Years	***Min***	***Max***	***Mean***	***Std***
2011	2.4205	2.5696	2.4765	0.0338
2012	2.1886	2.4493	2.3142	0.0511
2013	2.3115	2.9655	2.5317	0.1734
2014	2.7516	3.1947	2.9051	0.0894
2015	2.6326	3.4609	3.0220	0.2087
2016	3.1757	3.7883	3.3519	0.1495
2017	3.7053	4.7192	4.1256	0.2444
2018	4.4801	7.8344	5.6595	0.9058
2019	5.9220	6.9545	6.2569	0.2691

3.3. Support Vector Machines

The support vector machines used to maximize the width between dependent support points in decision making are the supervised learning algorithms developed by Vladimir Vapnik and Alexey Chervonenkis. It is successfully used in applications such as pattern recognition, time series analysis and classification. The SVM can be applied to both linear and nonlinear data. The SVM uses a kernel function that maps the inseparable input data to a higher dimensional hyperspace. The purpose of SVM is to find an optimal separating hyperplane by maximizing the margin between the separating hyperplane and the data set [16]. The function that is carried the nonlinear x data sequence to the higher dimension is defined as the mapping function and is indicated by $\Phi(x)$. In this case, the regression process is carried to the high-dimensional area with the kernel function

$$K(x_i, x_j) = (\Phi(x_i, x_j)^T \Phi(x_i, x_j) + 1)^p \quad (7)$$

where p is the degree of polynomial.

3.4. Statistical Error Criteria

The statistical error criteria given in Table 3 are used to calculate the error in the exchange rate forecasting. In the model evaluation stage, the performance of the financial time series forecasting model is measured by taking into account the mean absolute error (MAE), mean squared error (MSE), and root mean squared error (RMSE) [17]. Pearson correlation coefficient, which is an indicator of the relationship between input and output, is calculated as in Table 3 [18]. The performance of the model has been tested on the USD/TRY and EUR/TRY exchange rates data set. For each exchange rate, the kernel scale value of model minimizing error are determined.

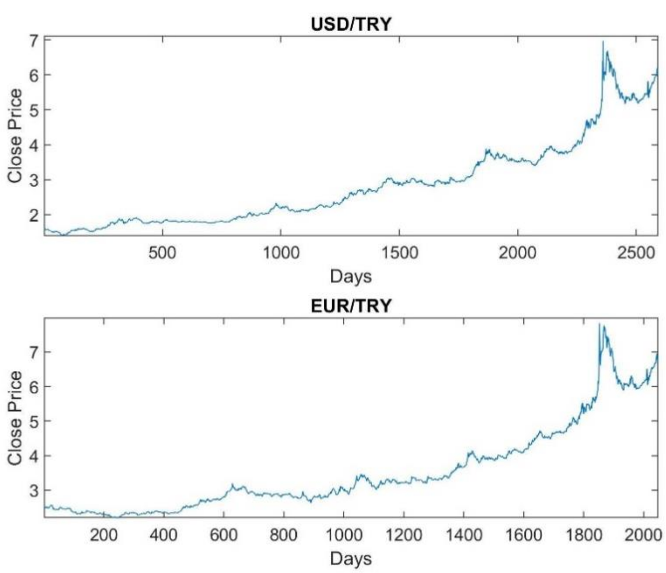

Fig.1. Closing price change for USD/TRY and EUR/TRY exchange rates.

4. RESULTS AND DISCUSSIONS

In this study, we estimate the closing prices of USD/TRY and EUR/TRY exchange rates for the next step with SVM. The financial time series data set consisting of 2593 samples between 2010 and 2019 years have been used for USD/TRY exchange rate. Similarly, the financial time series data set consisting of 2049 samples between 2011 and 2019 years have been used for EUR/TRY exchange rate. These data sets consist of daily closing price, minimum price, maximum price and trading volume parameters.

For SVM model, kernel scale values are changed between 0.5 and 10 with 0.5 step size and the model that has the minimum error has been obtained. 10-fold cross validation method has been used in the model training stage. The delay step for the WMA filter is set to 3. In addition, the CCI oscillator value has been used with the previous step value in the model input. The MSE changes of the models identified by different model parameters for both exchange rates are given in Figure 2 and 3, respectively. When the kernel scale value is 4, it is seen that the MSE value is the minimum for both exchange rates.

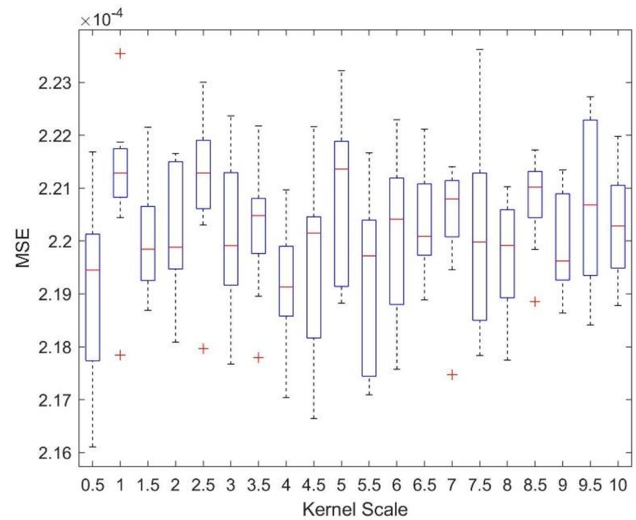

Fig.2. MSE changes for kernel scale values of USD/TRY exchange rates.

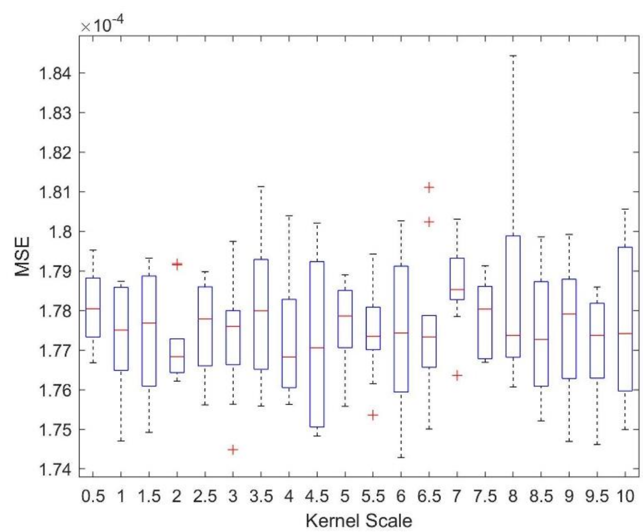

Fig.3. MSE changes for kernel scale values of EUR/TRY exchange rates

TABLE III
ERROR METRICS FOR EVALUATION OF MODEL

$$MAE = \frac{1}{M}\sum_{k=1}^{M}\left|p_{estimated}^{k} - p_{real}^{k}\right|$$

$$MSE = \frac{1}{M}\sum_{k=1}^{M}(p_{estimated}^{k} - p_{real}^{k})^2$$

$$RMSE = \sqrt{\frac{1}{M}\sum_{k=1}^{M}(p_{estimated}^{k} - p_{real}^{k})^2}$$

$$R = \frac{\sum_{k=1}^{M}(p_{real}^{k} - \overline{p}_{real})(p_{estimated}^{k} - \overline{p}_{estimated})}{\sqrt{\sum_{k=1}^{M}(p_{real}^{k} - \overline{p}_{real})^2}\sqrt{\sum_{k=1}^{M}(p_{estimated}^{k} - \overline{p}_{estimated})^2}}$$

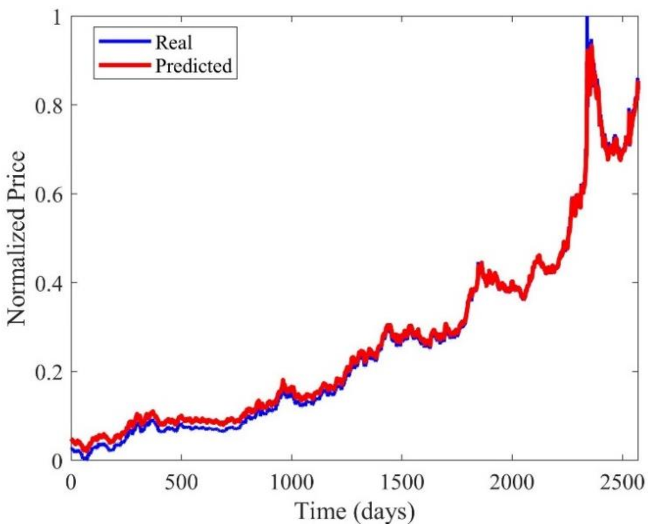

Fig.4. Forecasting results for USD/TRY exchange rates with kernel scale=4 in SVM model.

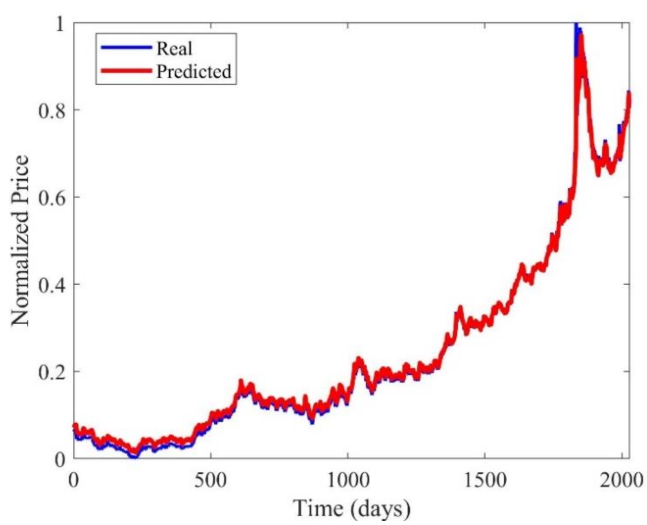

Fig.5. Forecasting results for EUR/TRY exchange rates with kernel scale=4 in SVM model.

The forecasting values for the model with the minimum error value for both exchange rates are presented in Figure 4 and 5, respectively. The regression curves of the best forecasting models for both exchange rates are shown in Figure 6 and 7, respectively, together with the Pearson correlation coefficient. The MSE, RMSE and MAE values of the proposed financial time series forecasting model for USD/TRY exchange rate have been determined as 2.1912×10^{-4}, 0.0148, 0.0122, respectively. The MSE, RMSE and MAE values of the proposed financial time series forecasting model for EUR/TRY exchange rate have been determined as 1.7666×10^{-4}, 0.0133, 0.0099, respectively.

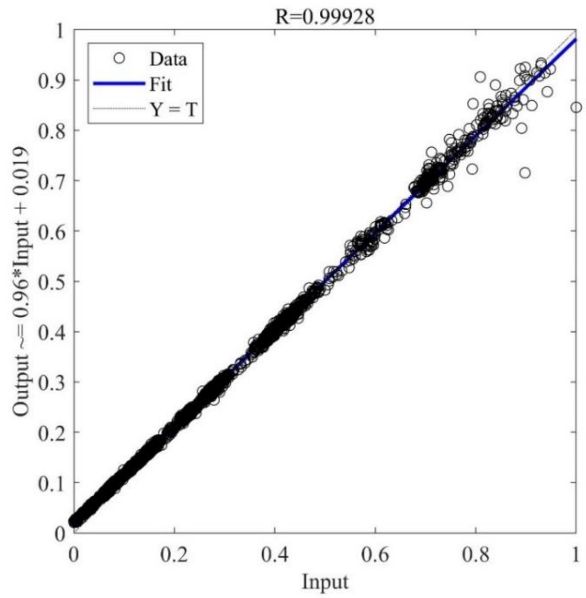

Fig.6. Regression curve in the case of kernel scale = 4 in the SVM model for USD/TRY exchange rate.

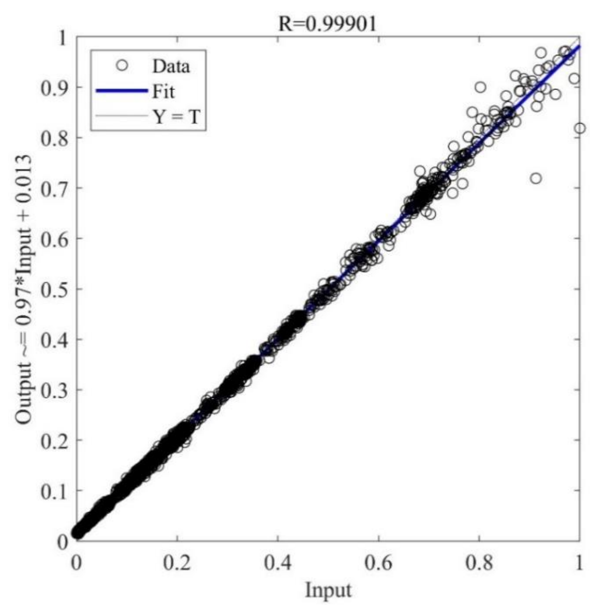

Fig.7. Regression curve in the case of kernel scale = 4 in the SVM model for EUR/TRY exchange rate.

5. CONCLUSION

In this study, the closing prices of USD/TRY and EUR/TRY exchange rates have been estimated for the next step with SVM, one of the machine learning methods. Financial time series consisting of daily closing price, minimum price, maximum price and trading volume parameters have been used in the study. The effect of different kernel scale values on the financial time series forecasting performance of SVM model has been investigated. The kernel scale value, which has the minimum error, has been determined. The USD/TRY and EUR/TRY exchange rate have been estimated by the SVM model with the determined kernel scale value. It is shown experimentally that the proposed forecasting model has high performance in forecasting the USD/TRY and EUR/TRY exchange rate consisting of financial time series. It is thought that this study will significantly contribute to the estimation of the volatility of different exchange rates with high performance. The proposed model will contribute positively to investors' cognitive decision making process.

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INVESTIGATION OF THE RELATION BETWEEN DOPAMINE DEPLETION AND THE SLOWING OF ALPHA RHYTHM IN ELECTROENCEPHALOGRAM OF THALAMUS

Y. Cakir

Abstract— A hybrid computational model of thalamo-cortical circuitry and basal ganglia is used to investigate the relation between the electroencephalogram (EEG) changes within the alpha frequency bands in thalamic region depending on the decrease in the dopamine level in striatum. Since it is known that in the diseases such as Alzheimer and Parkinson, the level of dopamine decreases, the related changes in thalamic region is investigated considering the dopamine depletion. The diseases affects the dopamine decrease in different ways, such that in Parkinsonian disease (PD), the total amount of dopamine affecting striatal neurons decreases whereas in Alzheimer disease (AD), the dopamine level decreases mostly in D2 dopamine receptor neurons. Therefore, these differences are analyzed to investigate the slowing of alpha rhythm on EEG of thalamus by using the modified mass model of thalamic region. It is observed that the decrease in the amount of dopamine causes shift of the power in alpha bands to lower frequencies. When the dopamine level is decreased in D1 and D2 type MSN neurons, the slowing of alpha rhythm in EEG of thalamus is prominent.

Keywords— *Alzheimer disease, EEG, dopamine, Parkinson disease*

1. INTRODUCTION

PARKINSON'S (PD) and Alzheimer's disease (AD) are the two of the most common seen progressive neurodegenerative disorders. PD is characterized by four primary motor symptoms: akinesia, bradykinesia, muscle rigidity and resting tremor. The brains of Parkinson's disease dementia (PDD) patients show extensive cholinergic loss as well as dopamine (DA) depletion [1]. In PD, the degeneration of dopaminergic neurons in the substantia nigra pars compacta (SNc) of the midbrain leads to the emergence of pathological activities in the basal ganglia–thalamic neural loop [2]. On the other hand, the AD is characterized by cognitive dysfunction and impairments in memory, the difficulties with memory, language, problem solving, since the neurons in the parts of the brain involving in cognitive function are damaged or destroyed. Neuropathologically, AD is characterized by the presence of extracellular amyloid β as plaques, hyper-phosphorylated microtubule associated protein tau and neurotic plaques that are composed of both amyloid β and tau. [3,4]. VTA and substantia nigra (SN) are the brain areas that are the origin of the dopaminergic cell bodies of the brain dopamine system. From the investigations in a murine model of AD, a significant loss of dopaminergic neurons in Ventral tegmental area (VTA), accompanied by reduced hippocampal innervation and declining memory was observed [5].

The alpha rhythm (8–13 Hz) in EEG signal is related to AD and PD. A transition of EEG from the alpha to the theta (4–7 Hz) band in an awake state is associated with the several neurological disorders including PA, and is termed as thalamocortical dysrhythmia (TCD). A similar symptom in AD is termed as "slowing" (a decrease of dominant frequency) of the alpha rhythms [6]. When compared to the resting state EEG rhythms of healthy elderly subjects, AD patients showed an amplitude increase of widespread delta and theta sources and an amplitude decrease of posterior alpha (8–13 Hz) and/or beta (13–30 Hz) sources. Diminishing power within the alpha band, referred to in literature as 'slowing' of alpha rhythms, is identified as a definite biomarker in the EEG of AD patients [7-10].

In this work, the influences of dopamine decrease in alpha band of EEG in thalamic region is investigated, since the diseases such as Parkinson and Alzheimer are related to the dopamine depletion in the striatum region of basal ganglia. Also, since a reduced number of D2 receptors in the striatum have been observed in AD [11], together with total reduction, the reduction only in D2 dopamine level is also investigated. The mass model of thalamus region and Izhikevich neuron based network model of basal ganglia are used in the analyses. It is observed that decrease in dopamine causes the shift of power to lower frequency component in alpha band, phenomena named as slowing in alpha rhythm. The total decrease (D1 and D2) in dopamine has prominent effect on slowing of alpha rhythm compared to only D2 dopamine level decrease.

2. BASAL GANGLIA THALAMIC NETWORK

The network consists of the basal ganglia and the thalamic regions of the brain as shown in Fig.1. The basal ganglia is interconnected with the cerebral cortex, thalamus, and other brain areas. It is associated with the functions, such as control of voluntary motor movements, procedural learning, habit learning, cognition and emotion. The main structures comprising the basal ganglia are the striatum, globus pallidus, substantia nigra and subthalamic nucleus (STN). The globus pallidus is divided into two functionally distinct parts, called the internal and the external segments, abbreviated as GPi and GPe. Substantia nigra has two parts: the pars compacta (SNc) and the pars reticulata (SNr). The striatum, the largest structure of the basal ganglia, mainly consists of Fast Spiking Interneurons (FSI) and Medium Spiny Neurons (MSN) including D1 and D2 type dopamine receptors.

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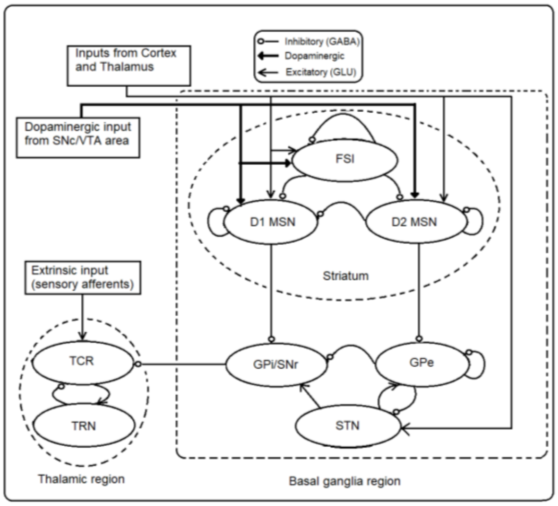

Fig. 1. Structure of basal ganglia thalamocortical network

In primates the SNr and GPi are part of separate circuits, with different target areas and sources of activity, but, despite these differences, GPi and SNr are often considered as a single structure due to their closely related inputs and outputs, also SNr works in unison with GPi, and the SNr-GPi complex inhibits the thalamus, therefore the the SNr-GPi are considered as a single neuronal population in the present model.

The striatum, GPi and GPe contain primarily GABAergic neurons having inhibitory effects on their connected post synaptic neurons. D1 MSN neurons project primarily to the output nuclei GPi and SNr, whereas D2 neurons project to the GPe. The GPe receives input also from STN neurons and other GPe neurons over local axon collaterals which have an inhibitory influence. The GPe sends an inhibitory projection to GPi and to STN. The subthalamic nucleus produces the neurotransmitter glutamate, which excites both the GPe and GPi/ SNr output nuclei. Striatal activity has excitatory effect on the thalamus via the D1 MSN neurons connection from the striatum to the output nuclei called direct pathway, and an inhibitory effect via the D2 MSN neurons connection to the output nuclei over GPe and the STN called indirect pathway. The two external inputs to network are glutamatergic cortical input and dopamine neurotransmitter originating from SNc region [2,12].

In the context of analyzing the changes in Alpha Rhythm in the case of diseases such as AD and PD, the thalamic region model is based on the previous work by Bhattacharya *et al*. [13]. In the present model, thalamic region consists of thalamo cortical relay (TCR) cells and thalamic reticular nucleus (TRN) considered as a mass model. The brain alpha rhythms are the most prominent in EEG from the occipital lobe in resting state. The external input to thalamic region represents the background firing rate represented as spikes per second of the retino-geniculate neuronal populations and is simulated by a Gaussian white noise. The inhibition effect of GPi/SNr part is obtained via connection over TCR population through the synaptic contact called as C_4. The detailed network model is given in Fig. 2.

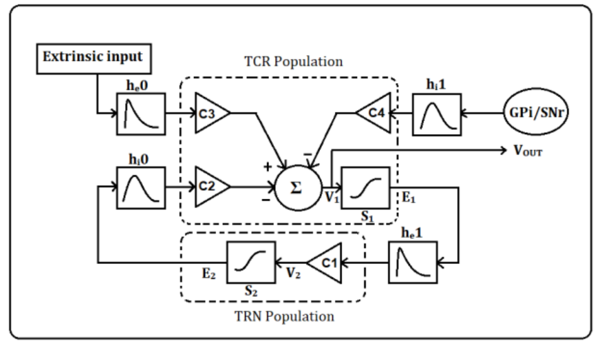

Fig. 2. Thalamic region mass model

2.1. Modeling of Basal Ganglia Network

The basal ganglia and thalamic network structure used in this work is initially proposed in the work by Cakir [14]. The basal ganglia part of network is modeled with Izhikevich neurons and consists of Striatum, GPi/SNr, GPe and STN neuronal population, each comprised by 20 neurons. Beside striatum, the other populations are modeled by the simplified form of Izikhevich neuron model given as,

$$\begin{aligned} \dot{v} &= 0.04v^2 + 5v + 140 - u + I \\ \dot{u} &= a(bv - u) \\ if\ v &\geq 30\ mV, then\ v \rightarrow c, u \rightarrow u + c \end{aligned} \quad (1)$$

where *C* is the membrane capacitance, v and *u* represent the membrane potential of the neuron and the membrane recovery, respectively. *a*, *b*, *c*, and *d* are dimensionless parameters. The input current I_i of any i'th neuron in this populations is expressed as $I_i = I_i^{app} + I_i^{syn}$.

The striatum consist of 3 types of neurons, roughly 10 % of them are FSI neurons, the half of the rest consists of D1 receptor type MSN and the other half of D2 receptor type MSN's. FSI neurons in the striatum have inhibitory GABAergic connections with the other FSI neurons and D1 and D2 MSN neuronal population. The D2 MSN neurons has inhibitory GABAergic connection with other D2 MSN neurons, D1 MSN neurons population and GPe neurons. The D1 MSN neurons has inhibitory effect on the other D1 MSN neurons and GPi and SNr populations. Since the effect of change in the amount of dopamine in striatum is investigated, the role of dopamine is included in neuron model. Dopamine has a dual action on MSNs; it inhibits the (D2-type) MSNs in the indirect pathway and excites (D1-type) MSNs in the direct pathway. The neuron models of D1 and D2 type MSN neurons and FSI neurons including the effect of dopamine are as,

$$\begin{aligned} C\dot{v}_{D1} &= k(v_{D1} - v_r)(v_{D1} - v_t) - u + I + \phi_1 g_{DA}(v_{D1} - E_{DA}) \\ C\dot{v}_{D2} &= k(1 - \alpha\phi_2)(v_{D2} - v_r)(v_{D2} - v_t) - u + I \\ C\dot{v}_{fs} &= k[v_{fs} - v_r(1 - \eta\phi_1)](v_{fs} - v_t) - u_{fs} - I \end{aligned} \quad (2)$$

where $\phi_1 g_{DA}(v_{D1} - E_{DA})$ is for simulating the hyperpolarizing effect of D1 activation. ϕ_1 is the parameter for specifying the level of dopamine for D1, $k(1 - \alpha\phi_2)$ is included to model increased sensitivity to the injected current following D2 activation, where ϕ_2 is the amount of dopamine [15]. Here *I* denotes the currents consisting of the externally applied and the synaptic current, $(I = I^{out} + I^{syn})$. The externally applied current is modeled as,

$$I^{out} = I_o + \sigma I_{cortical} \quad (3)$$

where I_o and σ are the constants, $I_{cortical}$ is a pulse shaped signal with unit amplitude and frequency of 2 spike/s, simulating cortical input [15]. The synaptic current of any i'th MSN neuron is given in Eq. 4.

$$I_i(t) = g_{gaba\_j} \sum_j r_{ij}(t-\tau_{ij})\left[E_{gaba\_j} - V_i\right] \quad (4)$$

where g_{gaba_j} is the chemical conductivity strengths, and τ_{ij} represents time delays from j'th presynaptic neurons to i'th postsynaptic neuron but time delay in this work was assumed zero during analysis. E_{gaba_j} is the reversal potentials for the inhibitory synapses and was taken as $E_{gaba\_j} = -60\ mV$. For each spiked connected neuron, the connection strength between these neurons is updated as $r_{ij} \leftarrow r_{ij} + \omega_{ij}$, here ω_{ij} is the inhibitory synaptic strength from neuron j to neuron i [16, 17,18]. During simulations the synaptic strength was taken as ω_{ij}=0.2 for all striatal neurons. r_{ij} is the dynamic variable that decreases exponentially depending on decay time τ_s as given in Eq. 5.

$$\tau_s \dot{r}_{ij} = -r_{ij} \quad (5)$$

Apart from MSN, the FSI neurons have synaptic connection only with other FSI's and also there exist a gap junction between FSI neurons that provide an extra current of electrical type. Therefore synaptic input for any I'th FSIs is,

$$I_i = g_{gaba_j} \sum_j r_{ij}\left(t-\tau_{ij}\right)\left[E_{gaba_j} - V_i\right]\ (1-\varepsilon\phi_2) + g_{gap}\sum_k [V_k - V_i] + I^{out} \quad (6)$$

where g_{gap} is the constant electrical synaptic strength from neuron k to i. V_k and V_i are pre and postsynaptic neuron's membrane potential. The network parameters are determined by considering the works by [2,12,18]. The parameters can be found in [14].

For investigating only the influences of dopamine decrease in the striatum sub network, the predefined connection between basal ganglia sub networks is established and kept the same during analyses. Every sub networks of basal ganglia is represented by the populations of 20 Izhikevich neurons having connectivity with the other populations as described in Fig 1.

Based on the findings mentioned in [2, 12], the connectivity for the rest of the basal ganglia network is established randomly but such that every GPe neuron receives inhibitory input from 2 MSN D2 neurons and two GPe neuron, and the excitatory input from 3 STN neuron. Every neuron from GPi/SNr population receives inhibitory input from two MSN D1 neurons, one GPe neurons and excitatory input from one STN neurons. Every neuron from STN neuronal population receives inhibitory input from two GPe neurons. STN neurons receive the applied currents from the cortical region also. The inhibitory connection to the thalamic region is from GPi/SNr population. However, since the mass model is used for the thalamic region, the inhibitory signal is obtained by using mean firing value of all neurons in this population.

2.2. Mass Modeling of Thalamic Network

The mass model of thalamic region was constructed by TRN and TCR cell populations. Every neuronal population in the model given in Fig. 2 is considered as a single entity having a soma which generates membrane potential *v(t)*. It is the sum of potential changes due to extrinsic and intrinsic inputs subsequently transformed into a mean firing rate using a sigmoid function. The TCR cell population receives excitatory input from an extrinsic source and inhibitory signal from GPi/SNr population. Since Alpha Rhythms are dominant in cortical EEG while a subject is in a relaxed but awake state, the extrinsic source represents a background firing activity of the neurons in the sensory pathway. They are simulated as Gaussian white noise having a mean, μ and standard deviation, ϕ.

The second-order differential equation corresponding to the postsynaptic membrane potentials of TCR and TNR neuronal masses are given as first order differential equations in the form of

$$\begin{aligned}
\dot{x}_{ret1} &= x_{ret2}\\
\dot{x}_{ret2} &= \frac{H_e}{\tau_e}P(t) - \frac{2}{\tau_e}x_{ret2} - \frac{1}{\tau_e^2}x_{ret1}\\
\dot{x}_{tcr1} &= x_{tcr2}\\
\dot{x}_{tcr2} &= \frac{H_e}{\tau_e}S\left(C_3x_{ret1} - C_2x_{trn1} - C_4x_{GPi_SNr1}\right) - \frac{2}{\tau_e}x_{tcr2} - \frac{1}{\tau_e^2}x_{tcr1}\\
\dot{x}_{GPi_SNr1} &= x_{GPi_SNr2}\\
\dot{x}_{GPi_SNr2} &= \frac{H_i}{\tau_i}\Delta V_{GPi/SNr} - \frac{2}{\tau_i}x_{GPi_SNr2} - \frac{1}{\tau_i^2}x_{GPi_SNr1}\\
\dot{x}_{trn1} &= x_{trn2}\\
\dot{x}_{trn2} &= \frac{H_i}{\tau_i}S(C_1x_{tcr1}) - \frac{2}{\tau_i}x_{trn2} - \frac{1}{\tau_i^2}x_{trn1}
\end{aligned} \quad (7)$$

The output of the model is the membrane potential of the TCR cell population defined as

$$V_{tcr} = C_3x_{ret1} - C_2x_{trn1} - C_4x_{GPi\_SNr1} \quad (8)$$

The parameter $H_{e,i}$ in the equation tunes the maximum amplitude of PSPs and $\tau_{e,i}$ is the lumped representation of the sum of the rate constants of passive membrane and other spatially distributed delays in the dendritic tree, where *e* represent excitatory and *i* represent inhibitory state [19]. Each connectivity parameter, C_i represents the synaptic contact. The connectivity parameter, C_4 reflects inhibitory effect of GPi/SNr neuronal population activity on TCR neuron mass. The sigmoid functions S(·) in (7) transform the membrane potential of a post-synaptic cell population into firing rate and is defined as $S(v) = \frac{V_{max}}{1+e^{r(V_0-v)}}$ where V_{max} is maximum firing rate of neuron population, V_0 is value of the potential for which a 50% of firing rate is achieved, also viewed as firing threshold, and r is the slope of sigmoid function.

$P(t)$ is extrinsic input simulated as Gaussian white noise. The $\Delta V_{GPi/SNr}$ is the deviation from the GPi/SNr population mean activity value obtained for the parameter set representing a healthy state (dopamine value 100%) dynamics in GPi/SNr population. This deviation is obtained as a difference of GPi/SNr mean activity values depending on the decreased value of dopamine. The parameter values of thalamic network used in simulations are given in Table 1.

TABLE 1. The parameters of mass model of thalamic region

Parameter	Value	Parameter	Value
H_e (mV)	3.25	V_0 (mV)	5
H_i (mV)	22	C_1 (%)	35
τ_e (mV^{-1})	10	C_2 (%)	15
τ_i (mV^{-1})	20	C_3 (%)	7
V_{max} (s^{-1})	5	C_4 (%)	10
r (mV^{-1})	0.56		

3. SIMULATION RESULTS

Since the dopamine level decrease in the PD and AD, the neuronal activity of proposed network is analyzed by reducing the amount of dopamine in D1 and D2 MSN neurons. The influences of decrease of dopamine in striatum and slowing in alpha rhythms in thalamic network depending on these decreases are investigated.

The basal ganglia and thalamic network model's equations are solved in MATLAB environment. The forward Euler method with a time-step of 0.1 ms is used in the simulations. For 8-13 Hz frequency alpha band analysis in thalamic region, a time interval of 60 seconds is used. The Fast Fourier Transform (FFT) is used to obtain the power spectrum of alpha rhythm. Prior to power spectrum analysis of alpha rhythm, the first 3 and last 2 seconds of simulation output vector V_{tcr} are discarded and the remaining part of the signal is sampled at 250 Hz and bandpass filtered, with a lower and upper cut-off frequencies of 7.5 and 13.5 Hz (alpha band), respectively, using a Butterworth filter of order 10.

The striatum region activity affects the remaining basal ganglia network via D1 MSN and D2 MSN neurons. The decrease in dopamine from its normal value, resembling the effect of disease, causes an increased activity in GPi/SNr neural population. Due to the nature of the diseases considered in this work, it is assumed that the network parameter changes occur slowly and progressively. Therefore, assuming that in healthy state, there is no disease based inhibitory effect to thalamic population from GPi/SNr, but, depending on the decrease in dopamine, there is emerging disease based inhibitory signal increase, it is decided to model inhibitory signal from GPi/SNr network to thalamus as deviation from mean value obtained in healthy state. The obtained difference $\Delta V_{GPi/SNr}$ is used as an input from basal ganglia to thalamic region mass model.

The parameter values in striatum are changed in such a way that the D1 and D2 MSN neurons' dopamine level is decreased from %100 to %50 and % 0. During the investigations, the cortical input and randomly produced white Gausian formed thalamic external input are kept the same. The results obtained for the initial parameter values are used as reference.

A short time interval, showing deviation in the membrane potentials of some neurons from basal ganglia network for dopamine value of % 100 are given in Fig. 3 as an example. In the network consisting of 80 neurons, the first 20 neurons represents the striatum region, the second 20 neurons represent GPi/SNr region, the 41-60 neurons are GPe population and the latest 20 neurons comprise STN population. The raster plots of all neurons in this time interval are given in Fig 4.

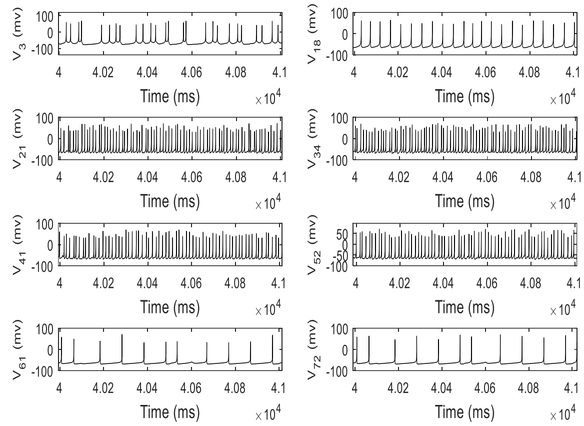

Fig. 3. The deviation of neuron membrane potentials between 40 and 41 s.

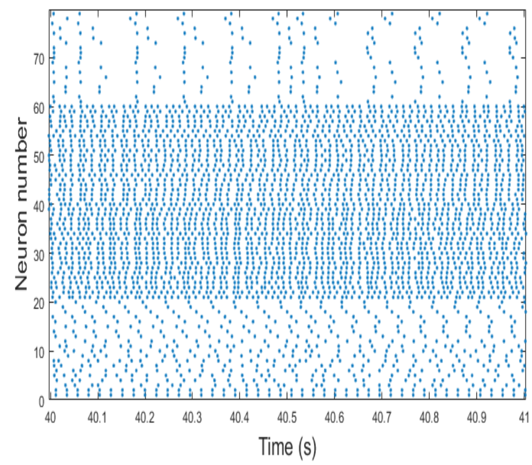

Fig.4. The raster plot of neuron populations in time interval between 40 and 41s.

From GPi/SNr population activities obtained for different dopamine values, the deviation from mean spiking value ($\Delta V_{GPi/SNr}$) is obtained and given in Table 2. As seen from table, the maximum deviation from the mean activity value is observed when D1 and D2 MSN neurons dopamine level decrease together. The decrease only in D2 dopamine level does not lead much increase in GPi/SNr population mean spiking value.

TABLE 2. The reference mean spiking value in GPi/SNr population and the deviation from this reference depending on dopamine decrease.

D1 MSN dopamine value (%)	D2 MSN dopamine value (%)	GPi/SNr population mean spiking value $V_{GPi/SNr, mean}$ (spike/s)	Deviation from the reference mean spiking value ($\Delta V_{GPi/SNr}$)
100	100	75.6262 (Reference value)	0
50	50	76.0248	0.3986
0	0	76.8706	1.2444
100	50	75.6779	0.0517
100	0	75.6607	0.0345

The effects of dopamine level on slowing in alpha rhythms are investigated by decreasing the value of dopamine from % 100 to %50 and % 0 respectively. The results obtained for the synaptic contact C_4=10 are given in Fig. 5.

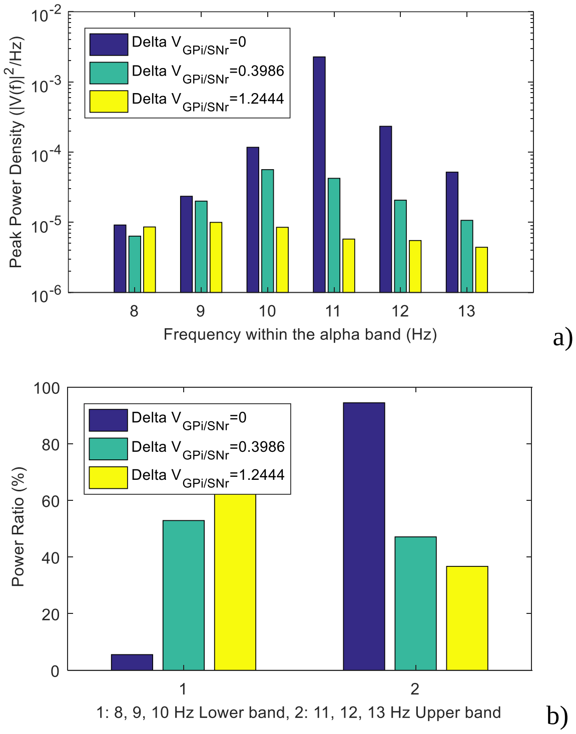

Fig. 5 a) Power density in alpha frequencies obtained for C_4=10 and D1 and D2 dopamine values of 100% , 50% and 0%. b) Power ratio in lower and upper alpha bands for corresponding dopamine values.

From Fig. 5a, it is observed that the ratio of power in lower frequencies (8-10 Hz) of alpha band increases compared to that of higher frequency (11-13 Hz) values. For a better view, the ratios of power related to the deviation in inhibitory signal $\Delta V_{GPi/SNr}$ are given in Fig. 5b. While the power in higher frequency of alpha band is over 90% for normal dopamine values, it decreases below 40% for zero dopamine value, meaning that power shifted to lower alpha frequency band, also named slowing in alpha rhythm is observed.

Since a reduced number of D2 receptors in the striatum has been observed in AD, in addition to the investigation of total reduction of dopamine, only the D2 dopamine level reduction is also investigated. The results obtained for 50% and 100% reduction of D2 dopamine level are given in Fig. 6. For dopamine level of 50% and 0% in D2, the deviations of inhibitory signal $\Delta V_{GPi/SNr}$ from its mean value are obtained as 0.0517 and 0.0345 respectively. Since the deviation from mean value is not as much as that observed when D1 and D2 MSN neurons dopamine level decrease together, the power in higher alpha bands does not change very much for the synaptic contact value of C_4=10. But for higher synaptic contact value such as C_4=100, the shift of power to lower alpha bands is observed as that seen in both D1 and D2 MSN neurons dopamine level decrease (Fig. 7). It is interesting observation that for 0% value of D2 dopamine, the deviation of inhibitory signal $\Delta V_{GPi/SNr}$ from its mean value is higher than that obtained for 50% decrease in dopamine. Therefore, the shift in the power to lower alpha band is not as high as that seen for 50% D2 dopamine decrease.

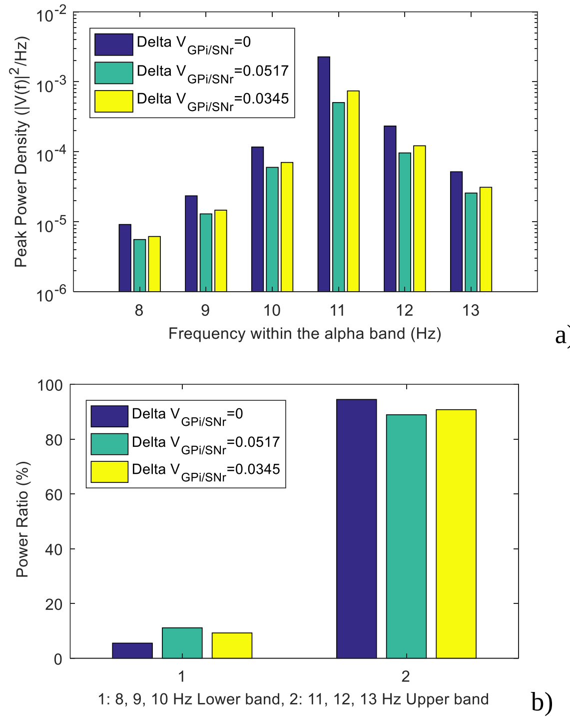

Fig. 6a) Power density in alpha frequencies obtained for C_4=10 and D2 dopamine values of 100% ,50% and 0%. The D1dopamine value is 100%. b) Power ratio in lower and upper alpha bands for corresponding dopamine values.

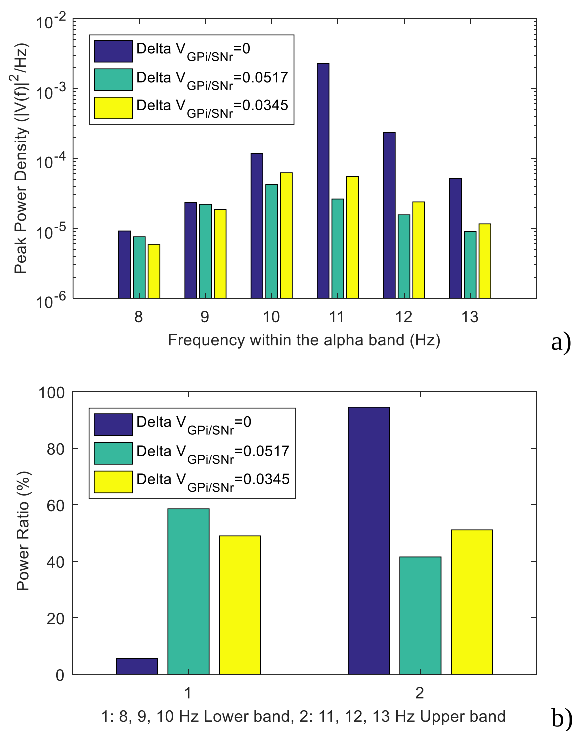

Fig. 7a) Power density in alpha frequencies obtained for C_4=100 and D2 dopamine values of 100% , 50% and 0%. The D1dopamine value is 100%. b) Power ratio in lower and upper alpha bands for corresponding dopamine values.

4. CONCLUSIONS

The relation between EEG changes within the alpha frequency bands in thalamic region due to the decrease in the dopamine level in striatum is investigated. For that purpose, a hybrid computational model of thalamo-cortical circuitry and basal ganglia is used. The mass model of thalamus region and Izhikevich neuron based network model of basal ganglia are used in the analyses. It is observed that the decrease in the amount of dopamine cause shift of the power in alpha bands to lower frequency values. When the dopamine levels of D1 and D2 MSN neurons decrease all together, the higher level of increasing inhibitory signal to thalamus is observed. This leads to a prominent slowing of alpha rhythm in EEG of thalamus. When only the dopamine level in D2 type MSN neurons is decreased, the slowing of alpha rhythm is observed for higher C_4 synaptic contact values. This is also a cognitive status of the brain.

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BIOGRAPHY

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EDUCATIONAL COMPUTER GAMES IN THE DETERMINATION OF VOCATIONAL TENDENS

E. İlkay and T. Sevindik

***Abstract*—** The concept of game is one of the oldest concepts in the life of the human being. People have always used the concept of game in their lives in order to have fun and to relax. But over the past forty years, traditional games have begun to change platforms and games have evolved from traditional to digital. In this context, a significant development has been seen as a process of digital game development in personal computers, palm electronic devices and mobile phones. Although it is seen as one of the most important problems in today's world, we should use digital games in order to reach positive results. In this study, a study has been done to determine the professional tendencies of computer games and primary school children. This research was extracted from the MSc Thesis and prepared for evaluation purposes.

***Keywords*—** *Game, Digital game, Vocational guidance, Cognitive interaction.*

1. INTRODUCTION

THE game is an experience that can be used for different purposes in various branches of science, whose history is known to be based on ancient times. Acording to TDK, the game has been defined as intelligence-enhancing entertainment, which has certain rules. [1]. Erşan (2006) stated that the game was an activity that existed in every period of life, the shape of the games, the characteristics of the games, the game materials varies for different cultures but is an unchanging universal feature for anywhere a child present. [2]. Montaigne stated "It should be noted that the games of children are not games, and must be considered as their most serious actions. For truly it is to be noted, that children's plays are not sports, and should be deemed as their most serious actions." [3]. Games have many benefits for people. Prensky listed some of them as follows [4].

1. Games are a form of fun. That gives us enjoyment and pleasure.
2. Games are form of play. That gives us intense and passionate involvement.
3. Games have rules. That gives us structure.
4. Games have goals. That gives us motivation.
5. Games are interactive. That gives us doing.
6. Games are adaptive. That gives us flow.
7. Games have outcomes and feedback. That gives us learning.
8. Games have win states. That gives us ego gratification.
9. Games have conflict/ competition/ challenge/ opposition. That gives us adrenaline.
10. Games have problem solving. That sparks our creativity.
11. Games have interaction. That gives us social groups.
12. Games have representation and story. That gives us emotion.

Prensky claims that nothing else can provide us with all of this. Books and movies, which perhaps come closest, have many of these characteristics, but they are not interactive, and are typically experienced alone. Games, at their best, are highly social, highly interactive experiences. [4].

2. THE PLACE AND IMPORTANCE OF THE GAME IN EDUCATION

Games are indispensable in children's lives. For this reason, it is the fact that the game is within the child's life makes it directly related to education. It is known that games contribute to the development of some skills such as focus and concentration. According to Amory and Seagram, the role of play in psychological, social and intellectual development is especially important in early childhood. [5]. Children learning through play can improve their social and cognitive skills, become emotionally mature and gain the confidence they need for new experiences and environments. [6]. Ghazali (1058-1111) also states that the game is important in the education of the child. According to him, play renews the memory of the child, increases the learning power and rests the child. Plato (B.C.427-347) emphasizes that the child should grow with play and that the game has an important place in the discovery of the talents of children. Poyraz (2003) and Öztürk (2001) also stated that the game enables teachers, parents and children to discover the hidden talents of children and that they can contribute to their education in this respect. [7].

3. DEFINITION OF COMPUTER GAMES

As a result of the rapid development of technology, computers have started to be found at homes, offices, schools and all environments. The transition to the computer age, as well as all sectors computer games were brought to the game industry. Oxford Dictionaries defines computer games as "a game played by a computer, usually a video game. A similar concept of video games is defined as "A game played by electronically manipulating images produced by a computer program on a monitor or other display" [8]. Kirriemuir (2002) states that the video and computer game concepts can be used interchangeably because of a screen in which the game is watched and data entry is provided by means of keyboard or joystick. [9].

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4. HISTORY OF COMPUTER GAMES

The introduction of computers into human life has affected people's many behaviours, such as getting information, sharing, socializing and entertainment, as well as playing behaviour. When we look at the history of computers, it is seen that people have met with computer games shortly after computers appear [10].

5. CATEGORIES OF COMPUTER GAMES

The concept of computer games has shown many diversity since their first appearance into life, both the devices used in the digital game and digital game genres. In this context, in order to classify computer games, Presky classifications are classified into 8 main categories [11].

- Adventure games
- Action Games
- Strategy games
- Simulation Games
- Role Playing Games
- Puzzle Games
- Sports Games
- Fighting Games.

6. COMPUTER GAMES AND DEMOGRAPHICS

DeKanter (2005) stated that today's learning generation is extremely game literate [12]. In addition, the National Institute on Media and the Family indicated that video games were part of the daily lives of almost all children, either directly or through friends and family members, and that 92% of children aged 2-17 years played video and computer games. [13].

7. BENEFITS OF COMPUTER GAMES AND EDUCATION

In addition to being a recreational activity for people, video games provide people with various benefits, such as developing active learning and critical thinking skills, building knowledge, and supporting access to and use of electronic form information. [14]. In addition, it is stated that computer games have the benefits of providing hand-eye coordination, spatial abilities, imagination, reasons of shapes, mathematical thinking with geometry, visualization of objects related to chemistry and physics, and integration of shapes in space. [9].

8. GAME DESIGN

Game design is the process of creating the content and rules of a game. Good game design is the process by which the player feels the motivation to reach and the process of forming the rules that the meaningful decisions that he / she will take in order to achieve these goals. [15]. When designing an educational game, it is necessary to combine game design with the theory of education and to determine the game goals in parallel with the educational objectives. This is called educational game design. In this research, which was produced from a master thesis, the focus was on the development of computer games in determining the professional tendencies of children and in this context, the importance of the concept of vocational guidance came to the fore.

9. VOCATIONAL GUIDANCE

A chosen profession of the individual determines;
a) Whether he / she has a permanent job throughout his life,
b) Whether he / she is a successful person in his / her life,
c) The nature and place of the environment to live in,
d) Income and livelihood of the family,
e) Whether to enjoy his / her job or not,
f) Whether there is a businessman with a sense of responsibility,
g) To provide satisfaction in general and to determine whether or not to be happy in life [16].

However, as Reeves and Karlitz (2005) reported, “There are approximately 12,000 kinds of professions known in the world. The diversity of occupations makes it difficult for the individual to make an appropriate career choice, and unfortunately, as Özgüven (2000) states, Many people are unaware of their interest and ability in the field before they start any work or activity. they can only discover after their experiences and their own interests. [18] This situation shows us the importance of occupational guidance in the life of the individual. We can describe the professional guidance, "help individuals to recognize various professions, choose professions appropriate to their qualifications, prepare for their chosen profession and develop professionally." In cases where vocational guidance and career counseling are insufficient, individuals can choose wrong professions due to many factors such as fears, concerns, misinformation and environmental impact. [19]. Therefore, vocational guidance plays a critical role in shaping the individual's educational life. At the same time, vocational guidance significantly affects the society and the state as well as the individual. Yeşilyaprak (2003) stated that the significant results of vocational guidance are emerging in the development of countries. [20]. Occupational guidance is a process that includes psychological and guidance services for students to prepare for their profession This process starts from the pre-school period and focus on the student's development period.

Vocational guidance helps individuals in the process of career selection;

- To helping them to reach realistic and objective information about professions,
- To help them discover their skills and skills,
- To help all professions to appreciate, appreciate and develop a correct attitude towards working,
- Help students to learn about existing colleges and universities,
- It aims to help the professional development period to gain professional development duties and help the next period to be ready for development tasks and so on.

In summary, vocational guidance helps students to make career planning in accordance with their personal, academic and social development.

10. CONCLUSION

As conclusion we can say that occupational preferences deeply affect the individual's life, living standards, social status and happiness in general. Therefore, it is vital for the individual to make the right professional choices. Here, an important responsibility arises for the instructors who will shed light on the student while realizing their vocational preferences. Vocational guidance processes are directly related to the abilities and interests of the individual and it is necessary to collect in-depth information about the individual. It makes. At this stage, it is critical that vocational guidance should benefit from the opportunities of developing and expanding new technologies.

Finally, since computer games, which are a part of the life of the new generation, have brought about significant changes in the way individuals express themselves, vocational support processes are supported by educational computer games that can provide in-depth information about the student. It can be said that more studies are needed to use as.

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BIOGRAPHIES

Emre İlkay was born on 26/07/1993 in Kayseri. After a year later my family moved to Amasya and I spend most of my childhood at there before my family moved again, this time Adana. I started my primary school in Adana at Vakıfbank İlköğretim Okulu and studied there for 3 years and several other schools. I went to Nedim Ökmen Anatoilan Teacher School. I graduated from Mustafa Kemal University in 2015. While when I still a student in university, I started game programming and I spent most of my free time on it since then. After graduation I started my master's degree at Yildiz Technical University and also started my professional life as game developer.

Tuncay Sevindik was born on 23/09/1977 in Bakırköy district of Istanbul. Started primary education at Hasan Kağnıcı Primary School and contained to Güneşli Secondary School, Mehmet Niyazi Altuğ Secondary School and Bağcılar Industrial Vocational High School. I graduated from Fırat University, Faculty of Technical Education in 1999. After that I started my master's degree in Educational Sciences in 2000 and completed my doctorate in 2007 at the same department. I continued my academic career as a faculty member since 2007, and since 2010 at Yıldız Technical University.

A NEURAL APPROACH TO DECISION MAKING UNDER UNCERTAINTY AND RISK

M. Irtem

***Abstract*—** The human brain is illustrated as the most complex object in the universe. From solving mathematics problems to choosing between coffee or tea at breakfast, the human brain makes thousands of decisions on a daily basis mostly under uncertainty, ambiguity or risk. Within its complex structure decision making processes play a significant role while activating many cortices, including but not limited to the orbital frontal cortex and the amygdala. On the other hand, decision making is similarly a complicated concept where uncertainty and risk are differentiated both theoretically in decision theory and anatomically in the human brain. Decisions are evaluated in the orbital frontal cortex and the ventrolateral prefrontal cortex with either value-based thinking or heuristic thinking. By uniting decision theory and the neural basis of decision making, we have learned how the human brain evaluates the available options and the possible outcomes and consequently reacts to the stimuli.

***Keywords*—** *decision making, uncertainty, risk, orbital frontal cortex, amygdala, dopamine system*

1. Introduction

AS it is defined in the Cambridge Dictionary, a decision is "a choice that you make about something after thinking about several possibilities''. Our lives consist of thousands of decisions we make every single day, whether to learn biology or history or simply to decide between wearing sneakers and heels. For something that affects our daily lives so much, we had very little information about it for a long time. After trying the solve the mystery behind the human brain, scientists began to wonder about the cognitive process of decision making. Decision making is described as a cognitive course of action due to the mental and logical thinking behind it. The progression of making a choice is a conscious action with various alternatives and consequently the desired outcome. But where does this mysterious process take place, and how does our brain respond to external stimulus and react accordingly?
Decision making isn't just a neurobiological process but rather a philosophical course of action as well. Therefore, one must first understand the philosophy behind it in order to comprehend the information about its cognitive neuroscience later on.

The human brain processes the stimulus and encodes it under two different types of decision making: value-based and perceptual. Value-based decision making is recognized by its subjectivity and its basis of preference. Under value-based decision making the outcome depends on chance, whereas under perceptual decision making it is determined by the choice, reward or penalty. Another difference between these two is the correctness of the situation. By value-based decision making, no outside factor determines the correctness of the situation, on the other hand, perceptual decision making is based on observations and objective criterion which defines the correctness of the response. Perceptual decision making has been the focus of psychological research whilst the attempt to discover the mysterious human brain. The word perceptual is defined as the objective principle that determines the correctness of the outcome. This implies that only one correct response exists. What happens when the decision maker is put in a position of uncertainty or risk, and what is the difference between these two? [1-9]

2. The Differences between Uncertainty and Risk

Any decision can be risky, uncertain or ambiguous, and these will most definitely affect the decision maker. When the decision maker has plenty of information about a situation, he/she makes the decision under certainty and therefore has the opportunity to choose the best alternative. On the other hand, the decision can be made under uncertainty, in which the decision maker has to search for information in order to act in a specific way. In addition to this, the ambiguity of the situation, which is when the decision maker has incomplete information about a situation's probability distributions, the outcome may make a distinction. This indicates that the level of information available to the decision maker is also a factor during decision making. Moreover, when the decision is made under conflict or risk, the decision maker has to predict the alternatives and the outcomes.

Furthermore, one must distinguish the difference between risk and uncertainty. A decision is described as risky when the options are well-specified or transparent outcome probabilities are presented, therefore, the decision maker can estimate the optimal response. In addition to this, under uncertainty, options and consequently outcomes depend on outside factors and the decision maker must calculate in vagueness, imprecision, and subjectivity. Several dissimilarities can be identified between risk and uncertainty. Simply, in risk-based decision making the decision maker losses or wins something worthy but under uncertainty future events or outcomes are unknown. Additionally, risk can be controlled, whereas uncertainty is uncontrollable, in other words, it is beyond the control of the person. Nevertheless, the choice made for a solution under risk may not be the best under uncertainty. Moreover, the cognitive processes observed are different under risk and uncertainty, value-based statistical thinking and heuristic thinking, respectively. As the Swiss mathematician Bernoulli stated, people do not weigh options by their objective value but rather by their utility or moral value. Consequently, risk-based decision making is better understood and easier to distinguish by decision theorists [9-18].

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3. THE ELLSBERG PARADOX

With his thesis *Risk, Ambiguity and Decision,* the man behind the leak of Pentagon papers influenced decision theory and behavioral economics remarkably. Daniel Ellsberg created the Ellsberg paradox, which explained how people make decisions under ambiguity or uncertainty. Generally, it has been discovered that people choose bad situations compared to uncertainty because they are risk averse but don't want to face uncertainty. Risk aversion is when people aim to refrain costly errors while avoiding aiming high and settling for mediocre results. Additionally, people tend to choose safety over joy considering one doesn't have control over change. But most importantly, people are twice as upset when they lose compared to when they win.

The Ellsberg Paradox is a comprehensive experiment to observe and understand risk- and ambiguity-aversion and subsequently decision making. They are two urns, containing 100 balls each, present in the experiment. The first urn holds 50 white and 50 black balls, and the player wins $100 with the correct bet. On the other side, the second urn contains 100 balls with an unknown ratio of white balls to black balls. When the probability of the tendency of choosing from the first urn or the ambiguous second urn is observed generally people have chosen from the riskier urn in comparison to the ambiguous urn. In other words, P (ambiguous white balls) < P(risk white balls) and P(ambiguous black balls)< P(risk black balls). People are willing to bet on the urn where the ball ratio is known and has a risky outcome than the ambiguous urn. However, these inequalities indicate a contradiction due to the fact that the probabilities of black and white balls for each urn must sum to 1, where 1= P (ambiguous black) + P (ambiguous white) < P (risk black) + P (risk white) = 1. This evidences the Ellsberg paradox, but the paradox can be solved by stating that the probabilities of the events are subjective and based on ambiguous outcomes.

The paradox has shown that people choose the urn with measurable risk compared to the urn with unmeasurable risk. This can be described as uncertainty or ambiguity aversion, which activates the fear system and consequently the amygdala. On the other hand, risk aversion can be noticed, which demonstrates the objective or subjective probability to get the reward. This implies the reward system and activates the striatum. The value and probability are evaluated in two different parts of the brain which are functionally and anatomically not united. The neurobiological aspect of decision making will be discussed in the following heading [19-25].

4. THE NEURAL BASIS OF DECISION MAKING

We have previously discussed the theoretical definition of decision making and the differences between decision making under risk and uncertainty and substantiated these with the Ellsberg Paradox. Now we will take a neural approach to decision making, in which we will primarily focus on the dopamine system, the amygdala and the orbital frontal cortex (OFC).

First of all, in the dopamine system, the neurotransmitter dopamine is produced, specifically in the midbrain. Dopamine is the primary substrate for the representation of decision utility. In addition to this, dopamine stimulates the action of liking without wanting, where one doesn't act but shows enjoyment after acquiring the reward. This is also called incentive salience, in other words, a motivational ‘’wanting’’ feature given by the brain. Furthermore, this alters the brains neural representations, for instance, it transforms a neutral or cold incentive to an attractive or desired incentive. This can be described as grab attention, whereas within the dopamine system a stimulus is transformed into an attraction and it is consequently neurally manipulated.

Another neural basis of decision making takes place in the amygdala. The amygdala is a subcortical structure responsible for the production of fear responses and understanding the connection between stimulus and these responses. In the amygdala, the negative outcomes are represented, and the experienced losses are handled. Neuroimaging has shown that the amygdala is active during awareness of losses. Moreover, we can use the Ellsberg Paradox experiment to understand the importance of the amygdala. It has been observed that control patients exhibit expectant response after practice, like choosing the less risky or positive expected outcome, compared to patients with amygdala lesions which do not learn to do this. In addition to this, the amygdala mediates fear conditioning and enables the person to exhibit fearful facial expressions. Patients with amygdala lesions fail to show any expression regarding their emotion, such as fear. Additionally, not only negative outcomes are represented in the amygdala but also the information concerning gains may also be encoded.

The most significant part of the brain where decisions are made, and the outcomes of those decisions are weighed is the orbital frontal cortex (OFC). The information about the probability of rewarding outcomes is used as well as the signaling of reward probability. In the OFC the predicted outcomes are mentally simulated, in which hypothetical or imagined outcomes are experienced. Interestingly, regret is also generated in the OFC. In addition to this, when a factor changes about the stimulus, the OFC helps by making an estimate in order to provide a reward.

There are two types of information regarding the time of the information being learned, newly-learned information and previously experienced information which may also be called the Pavlovian conditioning in this matter. Pavlovian conditioning can be described as the passive learning of neural conditioned stimulus and subsequently rewarding or punishing outcomes. The OFC is not necessary for such Pavlovian conditioning, for instance for a previously experienced behavior which is pre-computed without combining new information. In comparison, the OFC is required for making predictions on newly-learned information and the original learning with new information.

On another note, research has been conducted concerning OFC damage which in our case, one identifies the risky choices but chooses them anyway without displaying anxiety. People with OFC damage shows no bodily or emotional signal, which makes them choose the risky or the poor choice. For instance, people with OFC damage tend to choose riskier options without any anticipatory skin response in experiments like Iowa Gambling Task. OFC damage can also be seen in real life decisions, which serve severe impairments intellectually and on traditional neuropsychology measures. Furthermore, people with OFC damage can be categorized as acquired sociopath, which makes them engage in high risk behaviors with short term rewards and likely negative outcomes for the decision maker's wellbeing. Additionally, the ventrolateral prefrontal cortex (VLPFC) is related with response inhibition and goal-appropriate response [26-27].

5. Conclusion

In conclusion, decision making is one of the most significant cognitive aspects that affects our lives on a daily basis. Whilst living in a stressful environment due to the modern world, one is forced to encounter several moments of decision making under risk and uncertainty every day. Decision making under risk and uncertainty show differences not only theoretically but also anatomically in the human brain. Primarily the orbital frontal cortex and likewise the dopamine system and the amygdala are responsible for decision making on a biological basis. Although plentiful is to be known concerning the human brain and specifically decision making, today we can understand how a stimulus is processed and a conclusion is made regarding an outcome.

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