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Methodology to Evaluate the Intensity of Subjective Response to Emotional Pictures

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Abstract - The paper presents the results of a study of human perception of emotional pictures within the valence-arousal theory of emotion. The study involved 2 stages - EEG recording during viewing of images of 2 valences - *happy* and *sad*. After each image, the participant identified the emotion first, and then responded to a Likert scale on the intensity of the emotionality of the picture. The main result revealed a significant difference in the assessment of the emotion intensity by the male and the female participants. Trait-related and gender-related indicators of brain activation - delta and theta waves - are discussed in the context of possible novel approaches to rehabilitation.

I. INTRODUCTION

Cognitive biometrics has long attempted to identify patterns of EEG activations, which underlie experiencing different emotions [1, 2, 3]. A number of models have been proposed to account for the diversity of subjective experiences, associated with given emotions, among which the valence-arousal model has been prevalent [4]. It represents each emotion along a positive-negative dimension, and its intensity as an orthogonal to the former dimension to reflect the underlying level of neural activation. Mapping meaningfully self-reports on the nature and intensity of the experienced emotion when viewing emotional images, however, onto recorded neural activations, has been a difficult and not always definitive process.

The present research aims at identifying possible factors, which may determine the *idiosyncrasy* of the observed neural activations in the EEG frequency maps. One such dimension can be gender. It is possible to observe differing patterns in male and female participants in respect to valence. It is also possible to observe different intensity of the experienced emotion. Another dimension, possibly orthogonal to the first, can be *emotionality* as a trait. The outcome of this study will have an important impact on the rehabilitation approaches that can be undertaken via brain monitoring technology in the future.

II. METHOD

This study was designed with the aim to determine whether, when given emotionally triggering visual stimulus, it is possible to retrieve patterns of emotions from the electrophysiological and verbal responses. A study was designed using pictures validated for *sadness* and *happiness* from the publicly available OASIS[2] database.

Participants. A female (FP) and a male (MP) participant took part in the experiment. FP was 25 years old and MP

[1]The experimental work was performed while the first author was with the Department of Electrical Engineering, Indian Institute of Technology Kanpur, Kanpur, India

[2] https://www.benedekkurdi.com/%23oasis

was 28 years old - a graduate student and a project employee associated with IIT Kanpur, India. They were without any significant physical health issues related to vision (colour blindness) or musculoskeletal problems. The participants were not familiar with the study context until before their arrival.

Ethics. The study was approved by the Institutional Ethics Committee (IEC), IIT Kanpur. All procedures conformed to the IEC guidelines for research involving human subjects. The participants were provided written information about the study and a consent form which they had to sign for their approval to take part in the study.

Hardware. This experiment was done using a gNautilus wearable wireless EEG signal acquisition system[3]. It has 16 active EEG electrodes g.SAHARA (G.Tec), each sampled at 500Hz with flexible electrode positioning option in compliance with the 10-20 electrode placement system. The acquisition system was integrated with the MATLAB Simulink environment and an external TTL circuit to mark the events. The common reference configuration was in place while setting up the electrode arrays.

The eyelink-1000 eye-tracker system was used to capture the gaze pattern and pupil dilation while the participant was attending to the visual stimulus. This data will not be analysed here.

Stimulus. Forty-two pictures depicting four unique emotional states were randomly presented to the participants as visual stimuli. These images were sourced from the OASIS database and were rated on the valence-arousal scale for four emotional states which were *happy*, *sad*, *anger* and *excitement*. In the current study only the *sad* and *happy* cases are presented. Example images of *sad* and *happy* valences are presented in Fig. 1.

Fig. 1. Example images of *sad* (left) and *happy* (right) valences

Procedure. The stimulus began by a resting period of 30 sec, followed by the task in which each trial included a 4 sec display of the image followed by an emotion recognition task and a five-point Likert scale to record user behavioural response, and a 4 sec inter-stimulus interval (ISI). Cases of a sharp discrepancy of the objective emotion, depicted in the picture, and the subjective report (e.g. *sad* pictures perceived as *happy*), were removed from the analysis. A total of 30 such trials were recorded. The EEG recorded the cortical activities during the stimulus presentation. The ISI was selected at 4sec to account for the retraction period after image exposure.

III. RESULTS AND DISCUSSION

Twelve pictures were identified as *sad* by the female participant in contrast to the *male* participant who described eight pictures as *sad*. Fourteen pictures by the female and ten pictures by the male participant were perceived as *happy*.

Fig. 2 illustrates the mean perceived intensity of the observed emotions *sad* and *happy* by both participants. Interestingly, these differed statistically. FM evaluated the intensity of the emotion as reliably

[3] https://www.gtec.at/product/gnautilus-research/

higher for both the *happy* and the *sad* emotion, F(1,15) = 8,27, p = 0,009 for the *happy* pictures and F(1, 21) = 15,79, p = 0,0012 for the *sad* ones.

Fig. 2. Mean value of participants' evaluation of the intensity of the emotion in the *happy* and *sad* pictures

It may be that female participants experience emotions with higher intensity than male participants. This will be tested in bigger samples of participants.

EEG data analysis.

***Happy* emotion.** Images 'a' and 'b' on the left depict EEG activity of the female participant, whereas images 'c' and 'd' on the right illustrate EEG activity for the male participant (Fig. 3).

The main observations are: a. Prominent frontal delta activity at 1Hz peaking at 4 micro-volts towards the left (F8) and reducing to around 1 micro-volts towards the right (F7).

Large activity towards the left temporal lobe is also seen, which fades to the left parietal at 1Hz and is more localised in the later region at 7Hz in b. which depicts the higher theta activity. The right frontal, temporal and parietal activations were observed which involves the 'feeling center' or the amygdala of the brain.

For the male participant, c. the 1Hz delta activity at the frontal, a similar temporal activation and consequently the parietal activity, were observed.

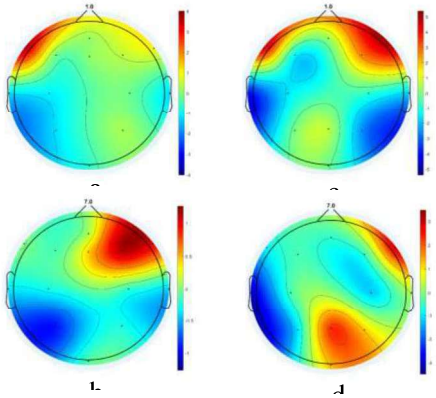

Fig. 3. EEG activations for the *happy* emotion (female to the left; male to the right)

These observations hold similarity to those of the female activations in 'a'. The right hemisphere dominance of theta (7Hz in d.) in the frontal area, is also parallel to that of the female in b. The left hemispheric dominance in the temporal and activations in parietal areas are important observations.

***Sad* emotion**. Images 'a' and 'b' (Fig. 4) on the left depict EEG activity of the female participant, whereas images 'c' and 'd' illustrate EEG activity for the male participant for the images perceived as *sad*.

a. In the delta band, at 3Hz, prominent frontal lobe activity is the activation over the left parietal area that extends to left temporal area. b. For the 7Hz theta band, the frontal activations at F4, F8, and inferior activations in the parietal occipital and temporal regions were observed. c. In comparison, at 3Hz, the frontal activity with dominance in the right hemisphere, occipital, and left temporal activity were observed for the male participant. d. The occipital theta activity at 7Hz, concurrently with the right temporal and frontal activations were observed.

The comparison of the brain charts reveals different patterns of activations for *sad* and *happy* images for both participants. Delta

and theta activity are the slowest waves in the human brain.

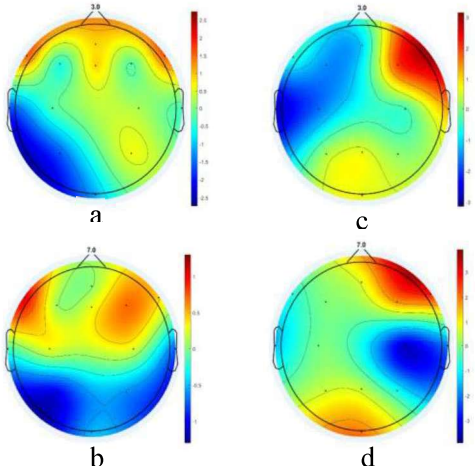

Fig. 4. EEG activations for the *sad* emotion (female to the left; male to the right)

Delta is associated with deep sleep and relaxation, whereas theta is associated with involvement of memory processes. Moreover, the involvement of delta in episodic memory formation during sleep was proposed in [5]. Since delta and theta are involved in forming and retrieving episodic memories, their involvement in EEG patterns while viewing *happy* and *sad* images, signifies the distinct way, in which memory is engaged, in viewing pictures of different valences. General indicators in the EEG activity have to be identified in order to be able to detect the valence of the emotion from the different way the memory is being engaged.

The gender difference in reporting the intensity of the observed emotion is the main outcome of the present study. It raises several issues. One possibility is that intensity is linked to *empathy* since the case involves viewing emotional pictures. In such a case this will be a trait feature, rather than a gender dimension. If, however, gender difference reaches significance, then this process will be beyond the trait theory and will require different EEG configuration to signify the gender in the EEG. Future studies will give answers to such questions in order to implement them in novel rehabilitation systems.

CONCLUSION

The paper presents the current methodology being implemented in order to be able to identify factors, which can influence the neural processing as reflected in the observed EEG patterns. The first novelty in our methodology was that we begin with the perception of the participants to the given images instead of imposing perception of the validated dataset. The later approach would miss out not only the actual perception of the participant but also a spectrum of emotions that a given instance of a picture can trigger in an individual given their unique past experiences, memories and thus their individual framework of emotion processing. The second perspective in the present study is that, followed by the participant perception of the emotions, their EEG activity is observed for traces of positive and negative emotion perception. Both individual differences and certain regularities were observed in the presented set of data.

Acknowledgement. The data used in this paper was collected at the Indian institute of technology Kanpur, and the EEG device was provided by Professor Bishakh Bhattacharya. I express my gratitude to Professor K.S. Venkatesh, Professor Naren Naik and Dr. Aravind .M, for engaging in discussions and their valuable inputs and queries that were useful in formulating the experiment design.

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Information Processing and Cybernetics

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Abstract - This paper traces the progress from signs, symbols, signals, communications and sequential processes to conversations that form the basis for information processing. All of these are involved in transferring information between individuals, and to accomplish this transfer they must often be capable of transmission over substantial distances in reasonably short time intervals. They must also avoid significant alteration by the environment in the course of their transmission. Claude Shannon provided a mathematical theory of communications that keeps the signal closer to the medium of transmission to ensure certain properties of what is getting transmitted. The complexity of the source and receiver are merely symbolized. The quest for complex methods of understanding information processing is useful for Cybernetic Control of the evolving complex Cyber – Physical Systems. There is a felt need to include matter and energy along with information as is currently specified.

Keywords - Communications, Cybernetics, Information Processing, Signal, Symbol

I. INTRODUCTION

Signs always have a clear meaning often giving information or an instruction. All Words are **Symbols** and this is how mathematics branched off from Spirituality that postulates "Word is God". The scientific thinking of mankind got well scoped, purposeful and abstract enough even if it is "unbound". Symbol is a character or glyph representing an idea, concept or object. Codified common set of graphic signs and symbols are used in all walks of life throughout the world. They are used in travel, agriculture, architecture, business, communications, engineering, photography, sports, safety, traffic controls, and many other areas to serve as valuable pointers for transacting the same associated actions quickly and effectively.

Important signs and symbols are visual representations of concepts, ideas, or messages that convey meaning and information quickly and effectively. These different signs and symbols are widely recognized and understood, often transcending language and cultural barriers.

By referring to objects and ideas not present at the time of communication as symbols, a world of possibility is opened. Symbolic communication includes gestures, body language and facial expressions, as well as vocal sounds that can indicate what an individual wants without having to speak in words of a chosen language. Research indicates that about 55% of all communication stems from such nonverbal language. Symbolic

communication ranges from sign language to braille to tactile communication skills. Symbolic communication is the exchange of messages that change a priori expectation of events.

Mathematics is comprised of primarily two things: Numbers and Symbols. It is now undeniable that symbols not only enhance understanding but also provide a universally perceivable manner in which to show a certain thought, concept, theory, function or illustrate a sequence. In simple words, without symbols, we cannot do mathematics that accords genericity. Mathematical symbols are aligned to the language of nature while the other "signs and symbols" are indicators of certain customs and conventions.

Notation is the act, process, method, or an instance of representing by a system or set of marks, signs, figures, or characters. **Denotation** is the primary, literal, or explicit meaning of a word, phrase, or symbol. **Connotation** is a meaning of a word or [set of words] phrase that is suggested or implied or predicated, as opposed to a denotation, or literal meaning. It brings along the idea of context. This is a reasonably unambiguous approach to representing any domain for scientific exploration.

Message is a written or spoken piece of information that you send to or leave for a person when you cannot speak to him / her.

A **signal** can be thought of as a higher-level abstraction representing an event or a piece of information, while a message is a more specific instance or realization of that signal in the context of communication between subsystems or components. It is possible that, in a given modeling framework, a subset of a signal could be considered a message.

Byzantine Generals' Problem is a game theory problem where in multiple different
Byzantine generals gathered around a besieged city with their own armies. However, they have to collectively decide when to attack. If all the generals attack at the same time, they win, but if they attack at different times they will lose. Some of the generals may be traitors. The loyal generals must agree to a plan of attack to win regardless of the action of traitors. The Byzantine Empire used a system of beacons [an optical telegraph] to transmit messages across Asia Minor to Constantinople. The main line of beacons stretched over some 450 miles [720 km]. A message could be transmitted the entire length of the line within an hour.

II. COMPUTING & COMMUNICATIONS

Communications in the realms of people has manifold manifestations and puzzling features. People communicate information, knowledge, error, opinions, ideas, experiences, wishes, orders, emotions, feelings and moods. Heat and motion can also be communicated. Likewise, strength, weakness and disease can also be communicated.

For the purpose of Computing and Communications, a mathematical theory of communications emerged. Please see the figure 1 below.

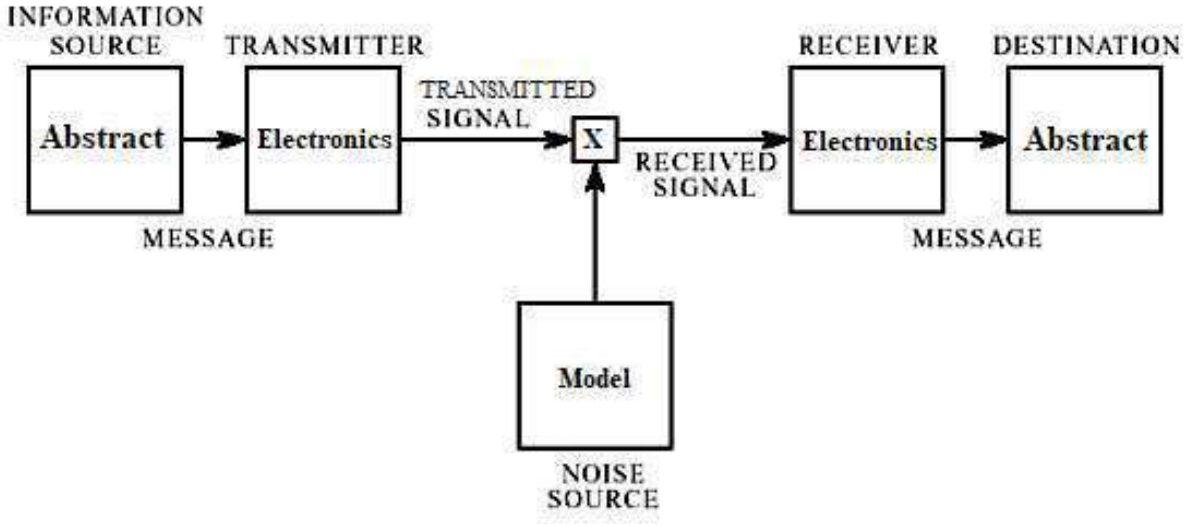

Figure 1: Adapted from Claude Shannon's Mathematical Theory of Communication

Shannon's brilliant idealization, defining a communication channel X between a transmitter and a receiver, and putting some constraints on the signals that could be sent along the channel, nicely captured one important aspect of information in its everyday sense. The utility of the Shannon concept of information, measured in bits, is evident in our confident calculations of bandwidth and the capacity. Bioinformatics could not exist without it. However, for a proper account of information that matters, that plays a role in getting work done at every stage and every level, the source and receiver cannot be taken merely as two homunculi [scale models of the human body] whose agreement on the code defines what is to count as information for some purpose. In other words, abstractions of the source and receiver are not adequate. Something has to play the roles of these missing signal-choosers and signal-interpreters. The mode of noise is another vital actor in this process.

Any information that is converted into an electronic form suitable for transmission across a channel is a signal. There are two types of signals i.e. analog and digital. The "information source" does the necessary conversion and the method is known to the receiver to retrieve the information. Signal is the actual entity that is transmitted from transmitter to receiver while the information is the content of the message. **Signal** is transmitted and **Message** is communicated.

In operating systems, a signal is an asynchronous notification sent to a process or thread to indicate a specific event or condition that needs to be handled as per a function specified apriori. Signals trigger specific behavior. In hardware, this is akin to an interrupt. Signals are often termed as "Software Interrupts". Computing is performed using the interrupts and signals.

The Coming Together of Computers and Communications has been feasible due to the peer to peer networking protocols to ensure Safe, Secure and Reliable Communications. ISO – OSI Reference Model is a comprehensive specification of the peer – to – peer relation and the networking protocols.

There are many technologies that illustrate the combined power of computing and communications. Agents and Communicating Sequential

Processes are discussed in brief in this paper.

2.1 AGENTS

An intelligent agent perceives its environment via sensors and acts rationally upon that environment with actuators. Please see the figure 2 below for an illustration of an Intelligent Agent using Signals and Messages. The illustration is simple and there is no consensus on what is an agent. Agent gets the interactions of autonomous co-operating processes with the environment, other agents and human. The agents can be mobile.

2.2 COMMUNICATING SEQUENTIAL PROCESSES

In computing, Communicating Sequential Processes (CSP) is a formal language for describing patterns of interaction in concurrent systems. It is a member of the family of mathematical theories of concurrency known as process algebras, or process calculi, based on message passing via channels. Please see the figure 3 given below.

A series of languages named Occam and Transputer as a machine architecture were ideal for demonstrating the increasing power of computation across networks with CSP. Handel – C is another formal language specification and there are variants of Java to support the CSP.

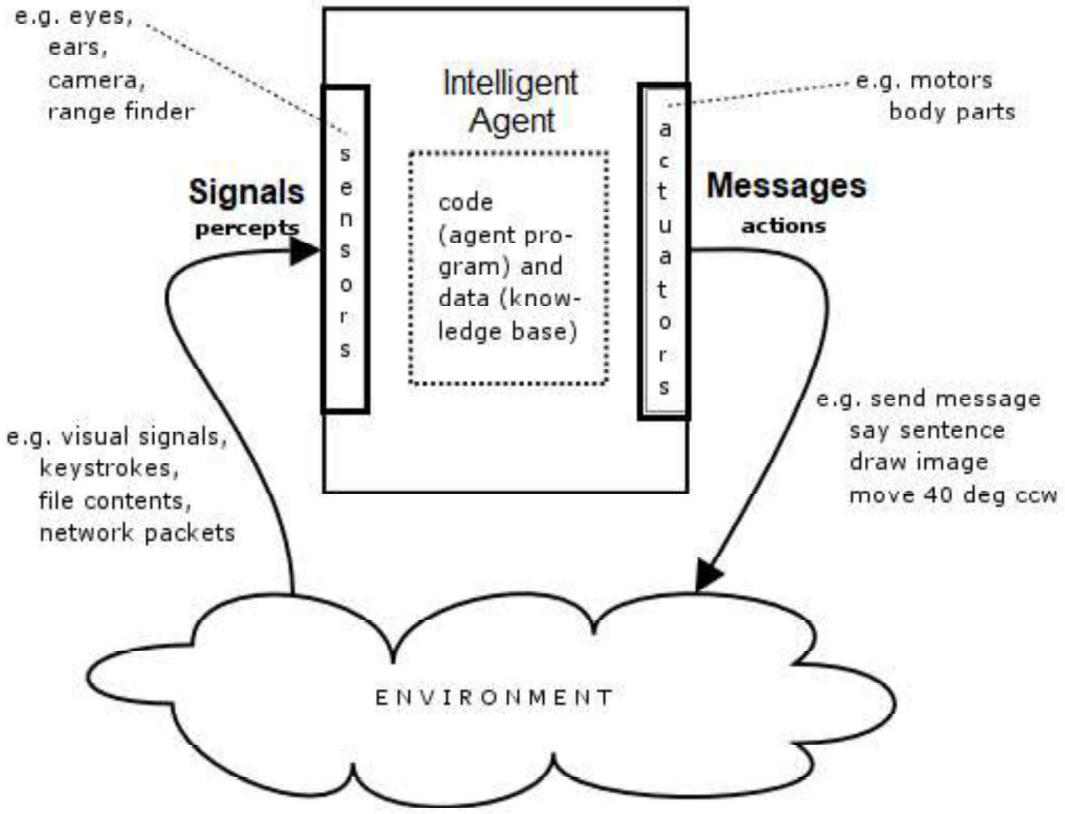

Figure 2: Intelligent Agent with Signals and Messages

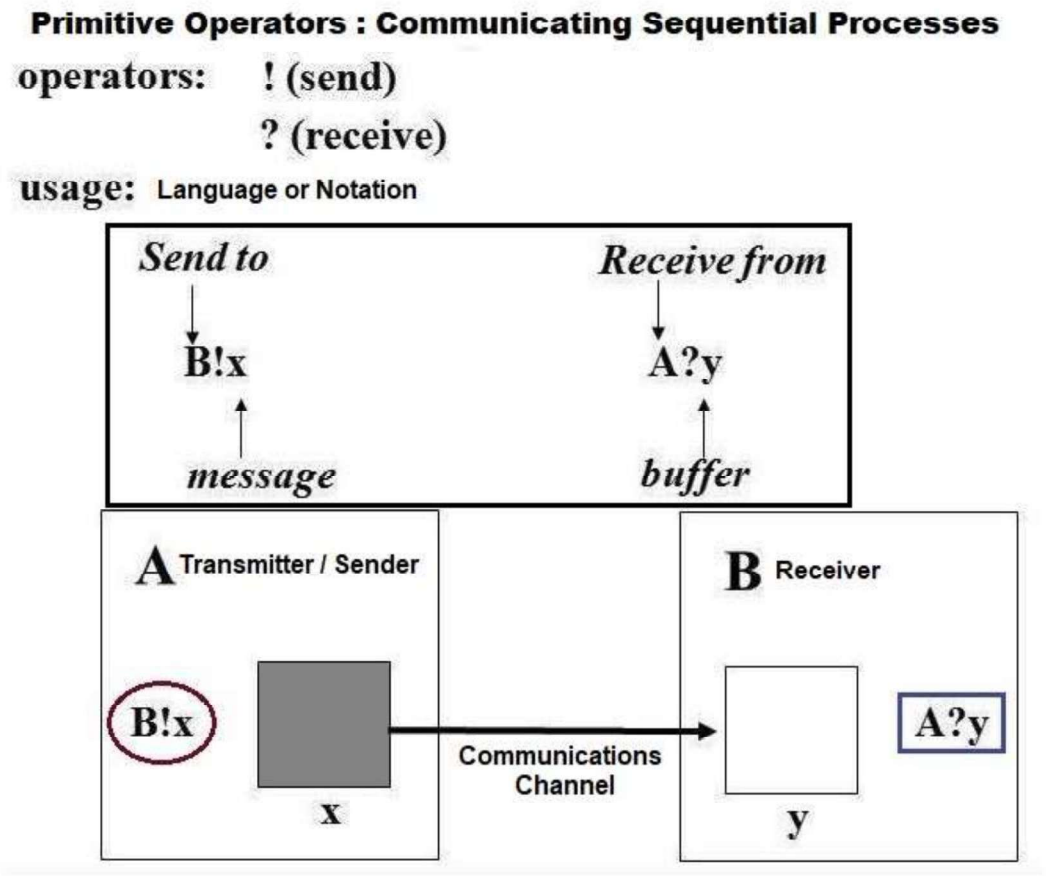

Figure 3: Primitive Operators for Communicating Sequential Processes

III. CONVERSATIONS

Conversation is an exchange of words, while communication is the transformation of thoughts and words into meaningful action.

Conversation typically involves what you wish to share with another; communication focuses more on what you wish to accomplish.

There are four types of conversations as outlined below.

- **Debate is a competitive, two-way conversation:** The goal is to win an argument or convince someone, such as the other participant or third-party observers.
- **Dialogue is a cooperative, two-way conversation:** The goal is for participants to exchange information and build relationships with one another.
- **Discourse is a cooperative, one-way conversation:** The goal to deliver information from the speaker/writer to the listeners/readers.
- **Diatribe is a competitive, one-way conversation:** The goal is to express emotions, browbeat those that disagree with you, and/or inspires those that share the same perspective.

There are three types of environment as outlined below.

- **Static (vs. dynamic):** The environment is unchanged while an agent is deliberating. (The environment is semidynamic if the environment itself does not change with the passage of time

but the agent's performance score does)

- **Discrete (vs. continuous):** A limited number of distinct, clearly defined percepts and actions.
- **Single agent (vs. multiagent):** An agent operating by itself in an environment.

"Bots" are more advanced than agents or the sequential processes used to illustrate the power of Conversations along with the coming together of Computing and Communications. However, information based approach is very limited to understand the Cybernetics and Evolving Complex Cyber – Physical Systems.

Prima Facie, both "bots" and "golems" were created by humans and their creation encompassed both material and mystical elements to serve humankind.

Cybernetics ushers in the "Control Information". It is not a thing or a mechanism but an attribute of the relationships between things. It is defined as: the capacity (know how) to control the acquisition, disposition and utilization of matter/energy in "purposive" (cybernetic) processes.

"Let us remember that the automatic machine is the precise economic equivalent of slave labor. Any labor which competes with slave labor must accept the economic consequences of slave labor." - Norbert Wiener, *Cybernetics*

IV. CONCLUSIONS

The full potential of Cybernetics in the realm of Signals, Communications, Sequential Processes and Conversations is being explored.

The following observations provide the some useful contexts.

- Cybernetic enhancements such as prosthetic limbs, microchip implants, and computer-brain interfaces may become a matter of fact sooner than later.
- In a survey conducted by a live chat app developer, more than 75% of people are willing to implant a microchip to monitor their health.
- As many as 74% of Generation Z respondents like the idea of upgrading their bodies with cybernetic enhancements. It is sort of human like forms collaborating with human beings towards a common goal.
- Indic Scriptures are replete with stories of grotesque figures that are worshipped through chants and incantations to bestow supernatural returns.

Matter and Energy - the top two concepts that have been traditionally deemed science's most fundamental seem to be running into the third i.e. information. The exact relationship within this the triad is a question without clear answers, a very vague question vague enough, always appears one of the foundational questions that inspire and evoke a wide variety of opinions.

The cybernetic triad i.e "Matter, Energy and Information" is at the core of evolving complex cyber – physical systems in these contexts. The core questions for the study are given below.

- Is a human form with remote controlled cybernetic implants a golem if there is exactly one code that can activate its built – in

functionality that makes it an enhanced human?

- Is there a way of remotely controlling this functionality?
- Can there be a built – in termination condition when the Creator loses control of the Creation?
- Who or What is playing God?

V. ACKNOWLEDGEMENTS

This paper is based on my two lectures for the Institute of Robotics, Bulgarian Academy of Sciences, Sofia, Bulgaria. The first one was in-person at the institute premises. The lecture was followed by stimulating interactions. The second lecture was on-line and was during the International Scientific Conference on the theme "Robotics and Mechatronics '23" (Collaborative Robots). Both the lectures were during April 2023.

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