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Cognitive Architectures for Enhancing Self-Directed Learning in Humanoid Robots

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Abstract: Feature of robots "on-going development" refers to the power to ceaselessly depend on what the system already is aware of, in association with an on-going method that acquires new skills and information, and achieves a lot of subtle levels of behavior. Human infants are presumably the most effective illustrious demonstrators of this ability. Developmental psychology has several results documenting the fact that what infants will and will not do at different ages. On the robots aspect, making a procedure system that displays on-going development continues to be an associate unresolved drawback. There are some questions that what features can be covered by the cognitive robotics development and what features are beyond the range of robots? In this research, comparative study is used for human infants and robots for realizing that why and what are features necessary for robots? How can they be useful to us? By which technology can they be achieved? We also realize that what features in infants are beyond the range of robots.

Keywords: Cognitive Development; Infant Development; Psychological Development; Artificial Intelligence; Limitation for ROBOTICS.

1. Introduction

Robotics are developed with the purpose of designing machines that look and act like humans. Robots can have many useful purposes in our life like disposal of bombs, robot-assisted non-invasive surgery, delivery of packets and parcels, war robots and pilot fewer planes. Despite all the factors robots are still in the early stages of its development.

The problem with the robots is that they are not self-learners as humans are. They follow the programmed module of instructions, making them not to think critically as a human does, by using their experience and common sense. This is an open challenge for the researcher to fill the gap between humanoid robots and humans.

Our objective is to design a mature and fully autonomous robot that can think and move around like humans. We have discussed the enhanced manner for developing a cognitive robot. Various experiments are performed among Honda Humanoid, iCub and Humans in the deliberation of psychological, physical and social activities.

The paper is structured as follows: Section II describes work related to the development of cognitive humanoid robot. Section III discusses the limitations of the learning process. Details of our methodology, bridging the gaps of previous researches are presented in Section IV. Section V provides tentative results of the comparison taken among human, Honda humanoid and iCub. We conclude in Section VI along with some of its future work and recommendations.

1.1. Contributions of the Research

This research proposes a new or improved cognitive architecture tailored for humanoid robots, enabling them to continuously learn and adapt autonomously. The architecture provides a foundation for self-directed learning, allowing robots to acquire new skills and knowledge without extensive human intervention. Secondly, by comparing the developmental processes of human infants with robotic systems, the study offers a unique perspective on how certain human cognitive traits can be replicated in robots. This analysis highlights which aspects of human learning are achievable in robots and which remain challenging. Thirdly, the research identifies critical features necessary for enabling self-directed learning in humanoid robots, such as memory retention, skill acquisition, problem-solving abilities, and adaptive behavior. These findings provide a guideline for building more autonomous robotic systems. Finally, this study contributes to the broader field of developmental robotics by offering strategies to bridge the gap between human cognitive development and robotic learning. It sets a foundation for future exploration in creating robots that can mimic human-like learning processes and behavior more effectively

2. Related Work

Historically, the makers of robots and intelligent agents have concentrated on mechanical-utility applications, for example, physical caretaking, unmanned vehicles, lawn- moving, factory work, stair climbers as well as presentation slides [1]. In 1970, one of the most prominent researches were started in the humanoid robot at Waseda University [2]. Later on, many educational and research institutions followed the paths of Waseda University for bipedal walking and humanoid research projects.

Moreover, the bipedal robot developed at Waseda University is the consequence of more than two decades of research [2], Honda's humanoid robots are the well-known humanoid robot these days [3].'ASIMO' [4] is the latest Honda's childlike humanoid robot. Sony developed a smaller kind of mobile robots named 'SDR-4X' humanoid robots [5]. This robot is mainly for the entertainment arcade. At the international level, high-tech learning can be structured in the form of gaming and competitions.

In [8, 9], self-organized pictorial development in the learner's visual circumstance of the mirror neuron system (MNS) is discussed. A self-learner robot learns from the role of MNS by associating self-induced engine commands with perceiving the motion. There are various commercial opportunities aroused by humanoid robots.

It is not an easy task to build even a walking humanoid robot. After ten years of intensive study and research Honda disclosed P2 and even after a few more years to initiate the ASIMO [7, 10]. Still, it is in continuous improvement phase.

The developmental mindset has addressed a problem of how the infants came to describe individuals as representatives having the intellectual conditions that are critical substance for the socialization. Particular studies suggested that the infants 'mental cognition is the peculiar ability of humans only. For example, Legerstee et al. [11] determined that a 6-month-old infant does not imagine people to communicate with the objects. These consequences specify that human intellect concentrates in initial infancy.

For a humanoid robot, there should be a cognitive behavior in the robot. For understanding human nature and its behavior, there are two different types of research available. 1. Erik Erikson Psychosocial Developmental Stages 2. Sigmund Freud's Psychosexual Theory of Human Development [12]. In these theories, the Erik Erikson theory is the most authentic and latest because he changed some rules and compared with many of basic assumption of the Sigmund Freud as with several psychologists whose work is primarily based in the psychotherapy. Erikson will be referred to as associate degree ego scientist. He checked on the stress of the id and a moderator between id and superego. Rather, the ego has a life of its own. Though part acutely aware and part unconscious, the ego additional clearly represents the overall temperament than will the id. With different ego psychologists, Erikson presented the importance of social interactions in development, as against Freud's stress on development as a representation method.

[13] Emphasis on physical robot development which is much better and profitable because it is vital to notice that biological plausibleness or similarity within the iCub isn't meant as a trustworthy of neural simulations to an awfully elaborated level. We have a tendency to don't assume that this method is possible given available hardware. Computing machine isn't a human brain, and it might be lavish to use computers for this purpose. On another side, gross options of design area unit biologically believable by together with attention, memory, action choice, grasping, reaching, and emotional states.

In [14] an approach for a psychological feature design for associate degree intelligent automation robotic system has been discussed. Two completely dissimilar models for such design are combined: on the one hand, design follows the strict stratified three layer idea through an occasional, middle and high level. While on the opposite hand behavior elements communication and interrelating with one another.

Their area unit psychological feature elements tailored towards psychological feature functions on to be found in masses. High-level and low-level vision play a vital role additionally as the attention management, communication components, discussion management, remembering, knowledge, advanced task coming up with, and control. There is enough area for further integration such as the feeling management, social communication or new learning modes.

To be helpful in all the environments, golem robots should always be ready to familiarize the existing abilities and want to address variations. They're conjointly needed to speedily learn fresh skills. Luckily, golem robots have a distinctive chance to be told from talented lecturers and humans. This is referred to as imitation learning [17] and programming by demo [18]. Imitation learning has been functionalized for different purposes, for instance, complicated motions like using a racket and producing gestures and expressions [19] and to influence tasks. The ability to express emotions for a robot should be same as of human. There are some researches to make a robot which can express emotions, usually through their facial terminologies [20, 21].

At MIT Lab in Cynthia Breazeal manufactured a robot head named Kismet. It is a part of the COG humanoid plan. Waseda's WE-3RE is basically a human resembling head specially designed for the humanoid robot [22]. This enables the humanoid robot to deal with the humans by human-like emotions. Emotions are manifested by means of lips, eyes and cheekbone reading or by vocal expressions. In [22], the Automatic Facial Expression Analysis system (AFEA) is discussed. It uses the 283 images for emotion specified expressions. Firstly, this method localizes the face section then extort face feature. Canny Edge Detector with No maximum Suppression (NMS) operator [15] and the Lucas-Kanade algorithm [16] is used to erect the feature vector and estimate the motion from frame to frame respectively. Model-Free tracking method is also used for estimating the motion of frame, but it has the problem of a similar feature in elongated arrange of images. Total recognition rates of this method by experiments are 95.76%.

An amorphous environment is required for a robot to work. There are numerous machine learning gears such as the neural networks [24], evolutionary systems [25, 26] and support learning [27, 28] have been used with the robot to learn the specific job. For instance, to let the bipedal robot to learn how to walk [29, 30], reinforcement learning algorithm has been applied.

The robots are supposed to be able to perform rationally on the basis of extensive information acquired about the problem and produce a desirable explanation for it. If the knowledge is insufficient, the robot gathers useful information by learning new information by examination. This field is still quite primeval, and a fresh outline for intelligence and is required to step forward the current restrictions.

3. Limitation in the Learning Process

Though there is a great advancement in the learning process of robots, still, they suffer due to some features. Some of the physical and psychological activities are much more difficult to adopt in robots. These are the following:

- Startling by performing an activity
- The mystery of hurting
- Raising a multilingual
- The parable of desire

The physical and psychological features stages that are not adopted by robots are shown in Table 1.

Table 1. Physical and Psychological Stages Limitation in ROBOTS

Development Features	Stages
Nappy Rash	Stage 1
Surviving Growth	Stage 1
Detective Work Pattern	Stage 1
The Mystery of Hurting	Stage 2

Raising a Bilingual	Stage 2
listening to Patterns	Stage 2
Teething	Stage 2
Preferring Music to Talking	Stage 3
Understanding flight	Stage 3
Knowing that Objects Move Themselves	Stage 3
Starting solid food	Stage 3
Differentiating Lullabies & Play-Songs	Stage 3
Encouraging communication	Stage 3
Sensing Conflict	Stage 4
Understanding the word ‘No’	Stage 4
Understanding Disappearance	Stage 5
Categorizing	Stage 5
Pairing Objects with Actions	Stage 6
Realizing Shapes Have Meanings	Stage 6
Developing the Pincer Grasp	Stage 6
Rising Memory	Stage 7

4. Methodology

The autonomous robot, in our proposed scheme, behaves much like a human. As many features and Capabilities are more likely to humans.

4.1. Recognizing You

It recognizes humans the way child learn to identify different faces. It uses the following characteristics to recognize human and save it in its database.

- Texture of Skin
- Shadows and wrinkles
- Shape of lips
- Eyebrow Shape
- Any jewelry
- Hair Shadow Length

4.2. Startling on the Basis of Recognition

The cognitive architecture of robot also introduced the feature in a humanoid robot that can sense human emotions and then behave according to it. It uses face recognition technique to recognize human face then face is segmented by edge detection. The proposed scheme in this module calculate Euclidean distance with the residing templates in database and determine emotion. On the basis of emotions, it behaves accordingly same as humans.

4.3. A Discerning Sense

The architecture of proposed methodology also stances a feature which makes this humanoid robot much closer to human. It can sense the environment by reading different signboards or notes using Optical Character Recognition feature. It converts the read image into a textual string, set of rules of activity of robot are maintained in the database. The appropriate rule is adopted for the robot’s activity.

4.4. Characteristics of Smoke, Smell, and Taste

The robot is considered the most deserted machine when it interacts with things that have odour, taste or smoke. The proposed architecture also has this feature which enables the robot to act appropriately when dealing with smoke by installing a grid of smoke detectors over it. It performs a desired activity from a set of rules defined in the database by deciding from multiple conditions like steam, black color, and detection of a cup ensure, it is a cup of hot coffee.

4.5. Loving Your Face

The face recognition system is installed in the proposed humanoid robot. The faces that are frequently recognized by it. It shows a level of great sincerity and loyalty to those face by obeying their orders. It shows a smile to those frequently visited faces; it seems as human nor robot.

4.6. Accepting Challenges

An autonomous robot behaves like a human. The robot in proposed architecture accepts challenges the same as a human. A list of corresponding acts is maintained in a database which response to the command of a person by recognizing his speech and act according to it.

4.7. Rising Emotions

The robot should show some sense of emotions. As humans have uniqueness from other creatures on the basis of emotions. Which makes them high ranked creature on this earth. As the proposed robot which is near to human, so it poses a sense of humor and emotions. It presents flowers and greets the persons on their birthdays. It maintains a database which contains human faces along with their birthdays and some greeting notes.

4.8. Kind-hearted with Users

Being more friendly towards users, it adopts some very interesting topographies if the robot has won the game thrice it loses the fourth game on its own to build interest for the user to play more. It ends up with some notes at the end of the game which encourages beginners. Chess game algorithm is imparted in this architecture with some additional features of greetings and behaving like humans.

4.9. Sleep and Wake up routine

To make it more similar to a human, it has the functionality of sleeping and waking up, which makes less energy consumption and less maintains cost. On the specified time it turns itself to hibernating mode, which gives a break to the motors, gears and other electronic components. It increases its life. Priorities options are also available in it, not to give a sleep break depending on the task robot is performing.

4.10. Depth, Shape, and Thickness of Perception

A human walks on the creepy and rough surface by viewing the surface through his eyes. His measure for depth is as long as he can see but the proposed robot uses a depth-sensing sensor, which uses a laser beam to determine how much depth is on any surface. Human results are not accurate, but this laser beam outputs accurate results. It also uses the tactile system a grid of touch switches to determine the shape and thickness of any object and surface.

4.11. Finding Partly Hidden Objects

As human recognizes partly hidden objects like e.g. a square, triangle or a circle due to the image he has built in his mind the same way our robot works. Object recognition module of the robot is advanced by an algorithm which predicts to which shape this partly hidden object resemble. On the basis of probability a desired shape is deducted.

This cognitive humanoid robot is built using the following technologies, object recognition, face recognition, facial expression detection, eye detection, optical character recognition, smoke and depth measuring sensors. Their combination made this robot much efficient and more cognitive for a human. It went through various implementation stages which are shown in Table 2

Table 2. Implementation Stages of Autonomous ROBOT

Functionalities	Stages
Knowing You from Others	Stage 1
Startling	Stage 1
A Discerning Sense of bit	Stage 1

Characteristic Smoke, Smells, and Taste	Stage 1
Loving your face	Stage 1
Accepting challenges	Stage 1
Rising Emotions	Stage 1
Kind-hearted with users	Stage 2
Sleep and wake routines	Stage 3
Depth, Shape and Thickness Perception	Stage 4
Finding partly Hidden Objects	Stage 5

5. Results and Discussion

The evaluation of this self- learner humanoid robot was the most important part of this article and had been carried out cautiously. It was compared with the residing humanoid robots on different stages. The comparison among human iCub and Honda Humanoid has been discussed in tables [3-9].

Table 3. Stage 1 Human vs. Robot

Developmental Activity	In humans	ICU B	Honda humanoid
Using his reflexes	1	1	1
Knowing You from Others	1	0	0
Repeating Mouth Movements	1	1	1
Startling	1	0	0
A Discerning Sense of bit	1	0	0
Getting head control	1	1	1
characteristic Smells, Sounds, and Tastes	1	0	0
Nappy rash	1	0	0
Surviving growth spurts	1	0	0
Detective work Patterns	1	0	0
Kicking	1	1	1
Combining Use of Senses	1	0	1
Combining Use of Senses	1	0	0
Loving your face	1	0	0
rising Emotions	1	0	1

As graphical representation are used to provide the better understanding to clarify, analyses, and interpret data easily. Graphical representation of the tables shown above are depicted respectively in figures [1-7].

Table 4. Stage 2 Human vs. Robot

Developmental Activity	In humans	ICUB	Honda humanoid
Bath time	1	0	0
let loose and Parents	1	0	0
Dummies	1	0	0
Listening	1	1	1
The Mystery of hurting	1	0	0
Age-appropriate toys	1	1	1
Interacting socially	1	0	1
Raising a Bilingual Kid	1	0	0
Developing hand-eye coordination	1	1	1
Correlating Dads and Diapers	1	0	0
Sleep and wake routines	1	0	0
the parable of Spoiling Baby	1	0	0
Pram Walks	1	1	1
Understanding Cause and Impact	1	0	0
Rolling over	1	0	1
proof of Memory	1	0	0
Rising Vision	1	0	0

Table 5. Stage 3 Human vs. Robot

Developmental Activity	In humans	ICUB	Honda humanoid
Blowing raspberries	1	0	0
Looking at herself	1	1	1
listening to Patterns	1	0	0
Teething	1	0	0
Synchronizing Sound with Movement	1	0	0
Talking the talk	1	0	1

Preferring Music to Talking	1	0	0
Understanding flight	1	0	0
Reaching	1	1	1
Matching Sound with Movement	1	0	1
Controlled crying	1	0	0
Knowing that Objects Move Themselves	1	0	0
Starting solid food	1	0	0
Understanding Stable and Unstable Objects	1	1	1
Solid food and allergies	1	0	0
mistreatment Primitive Arithmetic	1	0	0

Table 6. Stage 4 Human vs. Robot

Developmental Activity	**In humans**	**ICUB**	**Honda humanoid**
Keeping her head up	1	1	1
creeping & judgment Depth Perception	1	0	0
Imitating speech sounds	1	0	1
Differentiating Lullabies & Play-Songs	1	0	0
From sitting to crawling	1	1	1
Reading Emotions	1	0	0
Working on his fine motor skills	1	0	0
Following things Out of Sight	1	0	0
Bearing weight	1	1	1
Encouraging communication	1	0	0
Learning regarding Moving & Stationary Objects	1	0	0
Creeping	1	1	0
Weaning	1	0	0
Finding partly Hidden Objects	1	0	0
Improving Memory	1	0	0
Sensing Conflict	1	0	0

Table 7. Stage 5 Human vs. Robot

Developmental Activity	In humans	ICUB	Honda humanoid
The Onset of chariness	1	0	0
Understanding the word 'No'	1	0	0
Establishing Temperament	1	0	0
Pulling up in bed	1	0	0
numeration Events in a very Sequence	1	0	0
Passing objects from one hand to the other	1	0	0
postponed Imitation	1	0	0
Understanding Disappearance	1	0	0
Supporting Baby's makes an attempt	1	0	0
Categorizing	1	0	0
Talking	1	0	1
Following Your Gaze	1	0	0
The Onset of chariness	1	0	0
Understanding the word 'No'	1	0	0
Establishing Temperament	1	0	0
Pulling up in bed	1	0	0

Table 8. Stage 6 Human vs. Robot

Developmental Activity	In humans	ICUB	Honda humanoid
Waving good-bye	1	1	1
mistreatment Tools	1	0	0
Standing alone	1	1	1
Pairing Objects with Actions	1	0	0
Bumps and bruises	1	0	0
Demystifying Separation Anxiety	1	0	0
Cruising	1	0	0
Understanding Attachment Hierarchy	1	0	0
Realizing Shapes Have Meanings	1	0	0

Combining Categorizing and Imitating	1	0	0
Moving with ability	1	0	0
Setting limits	1	0	0
Developing the Pincer Grasp	1	0	0
Waving good-bye	1	1	1
mistreatment Tools	1	0	0
Standing alone	1	1	1

Table 9. Stage 7 Human vs. Robot

Developmental Activity	In humans	ICUB	Honda humanoid
Daytime sleep	1	0	0
rising Memory	1	0	0
Social Referencing	1	0	1
rising 1st Words	1	0	1
Walking	1	1	1
The Importance of informing	1	0	1
Daytime sleep	1	0	0

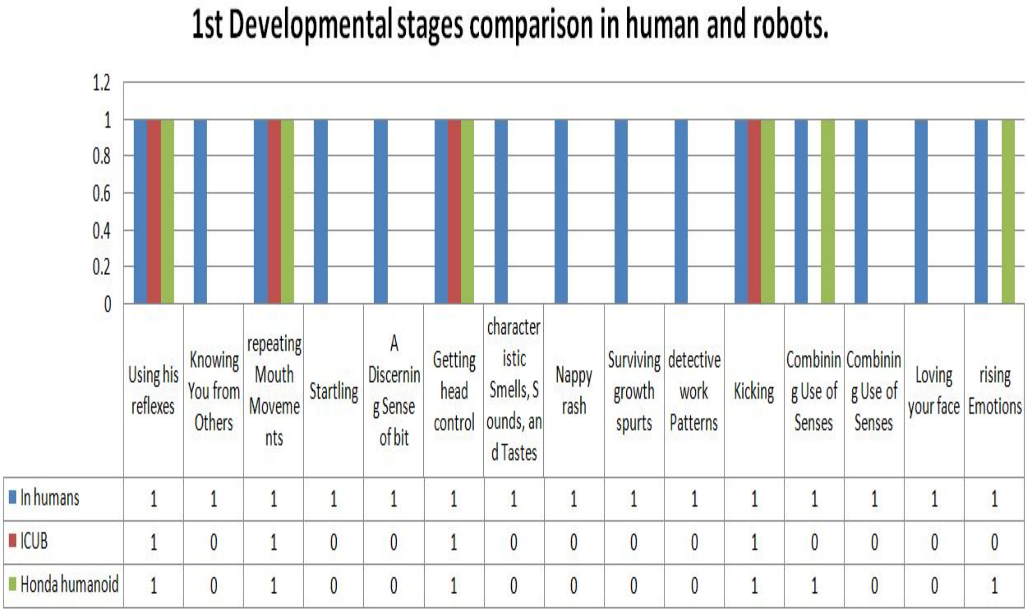
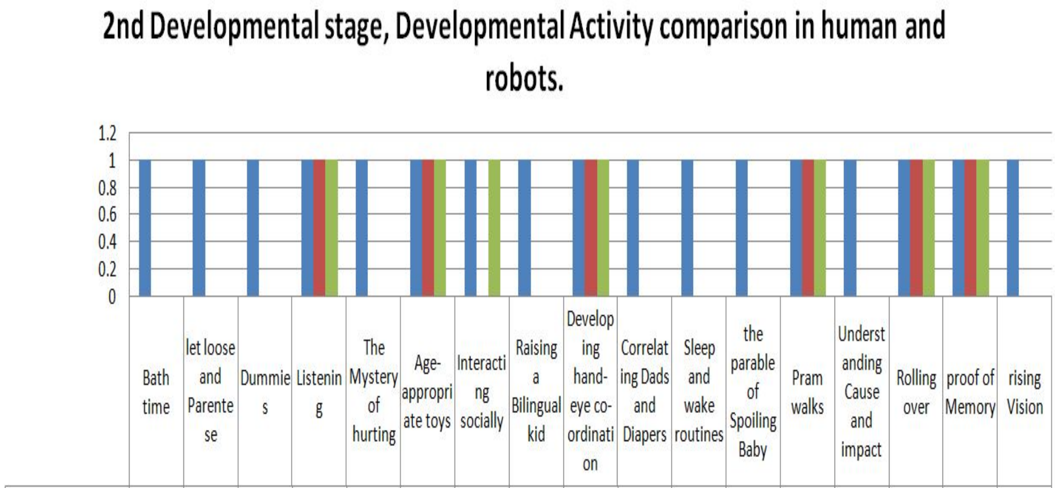
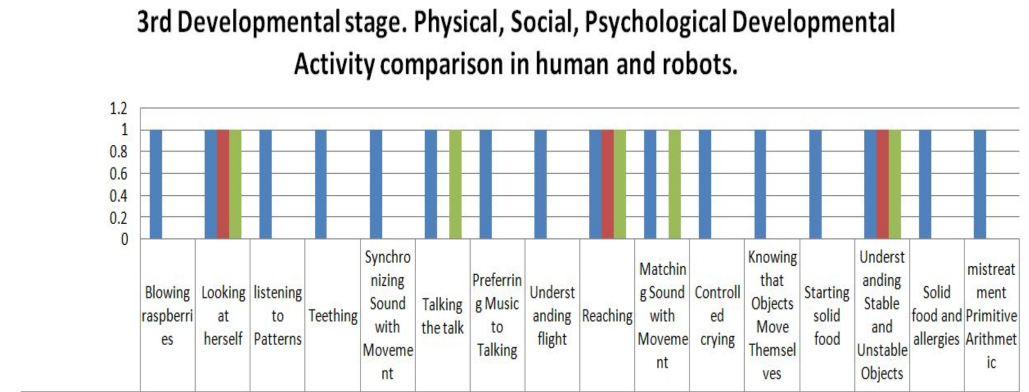


Figure 1. Stage 1 Human vs. Robot



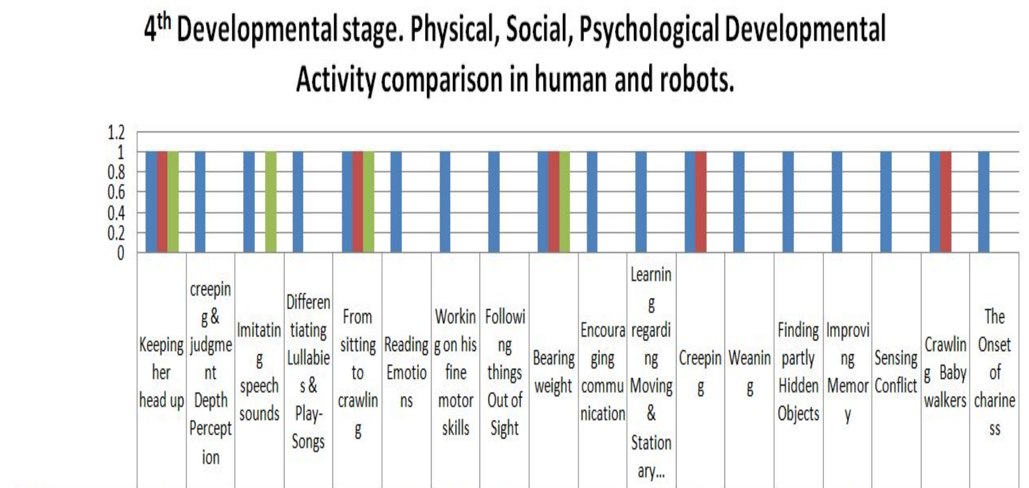
	Bath time	let loose and Parentese	Dummies	Listening	The Mystery of hurting	Age-appropriate toys	Interacting socially	Raising a Bilingual kid	Developing hand-eye co-ordination	Correlating Dads and Diapers	Sleep and wake routines	the parable of Spoiling Baby	Pram walks	Understanding Cause and impact	Rolling over	proof of Memory	rising Vision
In humans	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
ICUB	0	0	0	1	0	1	0	0	1	0	0	0	1	0	1	1	0
Honda humanoid	0	0	0	1	0	1	1	0	1	0	0	0	1	0	1	1	0

Figure 2. Stage 2 Human vs. Robot



	Blowing raspberries	Looking at herself	listening to Patterns	Teething	Synchronizing Sound with Movement	Talking the talk	Preferring Music to Talking	Understanding flight	Reaching	Matching Sound with Movement	Controlled crying	Knowing that Objects Move Themselves	Starting solid food	Understanding Stable and Unstable Objects	Solid food and allergies	mistreatment Primitive Arithmetic
In humans	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
ICUB	0	1	0	0	0	0	0	0	1	0	0	0	0	1	0	0
Honda humanoid	0	1	0	0	0	1	0	0	1	1	0	0	0	1	0	0

Figure 3. Stage 3 Human vs. Robot



	Keeping her head up	creeping & judgment Depth Perception	Imitating speech sounds	Differentiating Lullabies & Play-Songs	From sitting to crawling	Reading Emotions	Working on his fine motor skills	Following things Out of Sight	Bearing weight	Encouraging communication	Learning regarding Moving & Stationary...	Creeping	Weaning	Finding partly Hidden Objects	Improving Memory	Sensing Conflict	Crawling Baby walkers	The Onset of chariness
In humans	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
ICUB	1	0	0	0	1	0	0	0	1	0	0	1	0	0	0	0	1	0
Honda humanoid	1	0	1	0	1	0	0	0	1	0	0	0	0	0	0	0	0	0

Figure 4. Stage 4 Human vs. Robot

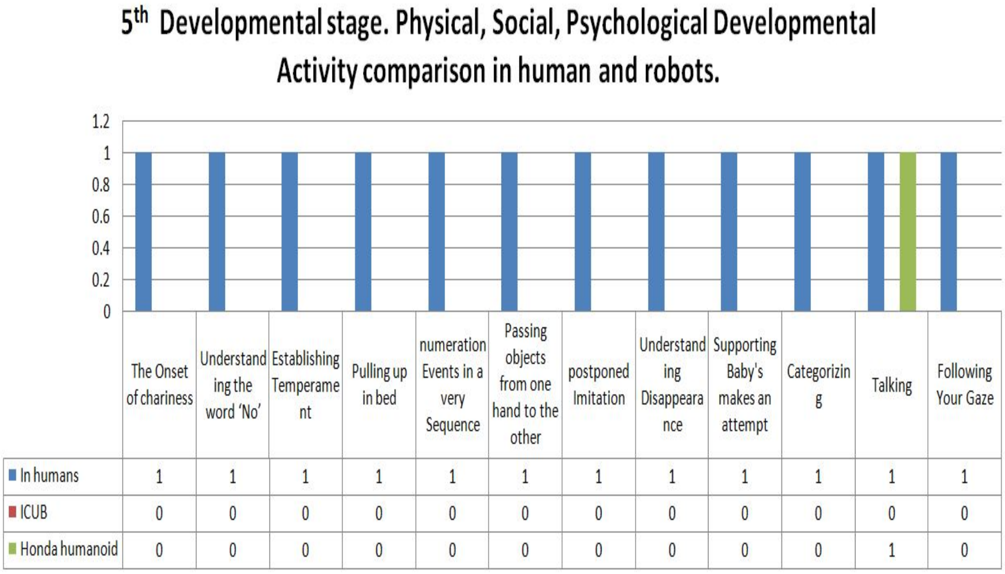


Figure 5. Stage 5 Human vs. Robot

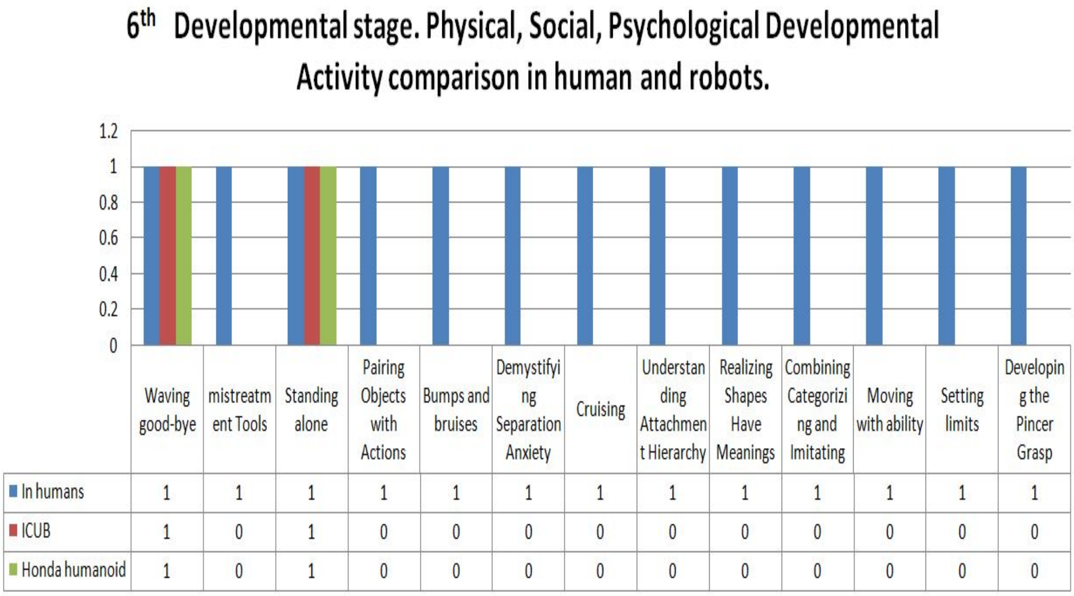


Figure 6. Stage 6 Human vs. Robot

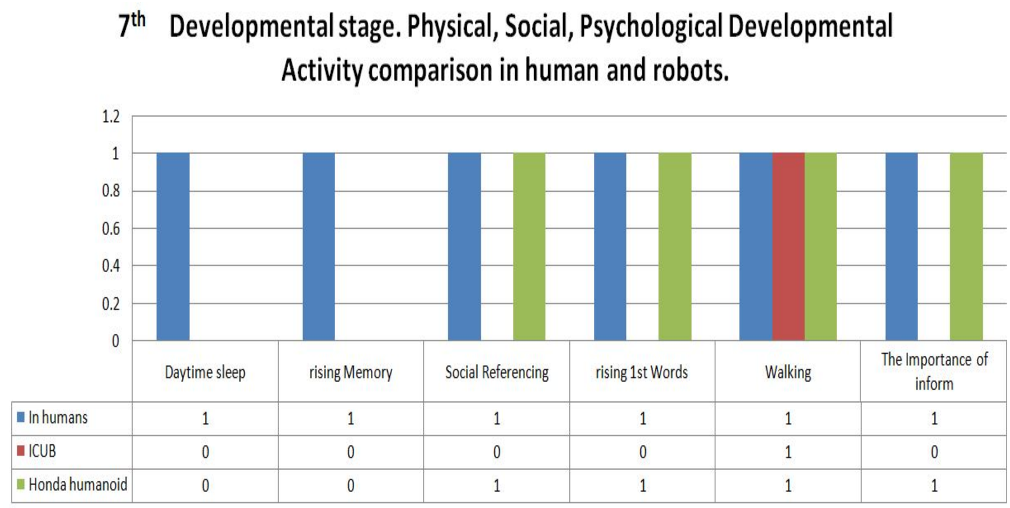


Figure 7. Stage 7 Human vs. Robot

6. Conclusion and Future Work

The present study for the development of humanoid robot shows many similarities between robots and human. It also enlightens the limitations for these robots. Some features to be accomplished by humanoid robot results in too much cost and it diminish many of its benefits. Those features include Hunger, Sex, Balance, Interaction Desire, Hope, Anger, Love, Thinking, Frustration, Fear, Belief, Passion, Arrogant, Reason, Violent, Hate, Dread, Depression, Religious, Mystic, Biased, Obsessed, Selfish, Opinionated, Aggressive, Grumpy, Racist, Neurotic, Morbid, Escape and Apathetic.

Many features are improved in the proposed humanoid robot which is accomplished by imparted modules such as Object Recognition, Face Recognition, Facial Expression Recognition, Eye Detection, and Optical Character Recognition, Optimal Mark Recognition, Smoke Sensing, Taste Sensing, Temperature Sensing, Distance Measuring and Depth Measuring sensors.

By the merging of all the above technologies in one robot results in much efficient and more cognitive for a human. This robot performs work with better efficiency as well as intellectual in the human environment.

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