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ADVANCEMENT OF ROBOTICS IN HEALTHCARE

Suhani Chawla

Jaspal Kaur Public School

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ABSTRACT

If robots are not common everyday objects, it is maybe because we have looked robotic applications without considering sufficient attention what could be the experience of interacting with a robot. This article introduces the idea of a value profile, a notion intended to capture the general evolution of our experience with different kinds of objects. In the past two decades, robotics has evolved immensely with increased prospects in biological, healthcare, medicine and surgery industry. Robots are being used in almost everything and almost everywhere. However, they are not to replace qualified human workforce, instead, assist them in routine work and precision tasks to achieve high throughput. Advancements in micro- and nano-robotic devices is very much dependent on innovations in micro-electro-mechanical systems (MEMS) and nano-electromechanical systems (NEMS) with collaborations among diverse domains of research viz., life science, medicine/surgery and engineering. This paper highlights the advancement of Robotics in Neuroscience, Medical Science and IOT in the context of Robotics.

INTRODUCTION

The term “Robot” was first introduced by Karel Capek (Czech writer) in 1921, way ahead of the existence of the very first real robots. Around twenty years down the line, term "Robotics" was coined by a Russian-born American sci-fi writer Isaac Asimov. Robotics tends to be an interdisciplinary sector of science and engineering with exclusive designing, construction and the understanding of utilization of diverse robot types distinctly (Kapur, 2005). Robots are now a days becoming the epicentre of research and application in numerous domains due to their potential use in making the day-to-day living more convenient (Wykowska 2021). Robots provide a plethora of uses and benefits, making them the ideal technology for the future. Soon, robots will be used almost everywhere. Robots have been majorly classified as industrial robots and service robots. Even the service robots can be sub-classified into personal/domestic service robots and professional service robots (Table 1; Table 2) (Bekey and Yuh 2008). The various sectors where robots find their use are manufacturing, assembly, packing and packaging, mining, transport, earth and space exploration, telepresence, entertainment, art, weaponry, laboratory research, schools, offices, safety, mass production of consumer and industrial goods, housekeeping and hospitality, healthcare, medicine, surgery, etc., to name a few (Figure 1). They are replacing all the old school methods of modus vivendi and are turning to be an impregnable asset for the mankind (Pagliarini and Lund 2017; Kornuta et al., 2019; Martinelli et al. 2021).

The robots are designed to be automated and intelligent. They use sensors, actuators and a control system producing motor actions from the sensory data to autonomously react with the environment (Mondada et al., 1994; Posadas, 2008). The first automated robot was built by neurophysicist William Grey Walter in the early 1950s with few interconnected neuron-like analog electronic devices, closing the loop between acumen 2 Advancement of Robotics in Healthcare, Medicine and Surgery and the action to produce complex and purpose-driven behaviours (Walter, 1950; Floreano et al., 2014). Simultaneously, “Unimate” was invented and patented as the first digitally operated and reprogrammable manipulator by George C. Devol in 1954 and it proved to be the very first industrial robot, which was brought into use by General Motors in 1961 (Bekey and Yuh 2008). With the advancements in robotics technology, industrial robots became popular around six decades back. In the late 1960s, Joseph Engleberger modified “Unimate” upon acquiring its patent and incubated Unimation (an organization for production, marketing and sales of industrial robots). For his contributions, he is known as the "Father of Robotics." In the year 1970, Charles Rosen and his research team from academic institution "Stanford Research Institute" developed "Shakey", a far more advanced industrial robot than "Unimate". It was the 1st mobile robot regulated by artificial intelligence. Since the advent of the preliminary robot prototypes to until 2010, the robotics market growth rate was very steady. However, 2010 onwards, this market has witnessed a real growth spurt and is expected to grow to a tune of ~USD 180 billion by the end of 2026.

HUMANOID ROBOTS AND HUMAN COGNITION

Robots are being modulated to create them into a potential tool for scientific inquiry in the field of experimental psychology for understanding human socio-cognitive traits through the implementation of computational models (Wykowska 2021). Thus, they may be a unique tool for generating new hypotheses, predictions and mechanistic explanations regarding human cognition. Human capabilities, limitations, biases and inclinations in a given situation varies from individual to individual and hence, an individual’s decision processing and results are variable across time, situation and other aspects. Thus, an individual’s behaviour can be remarkably influenced by variations in physiological and psychological states (Makeig et 3 Advancement of Robotics in Healthcare, Medicine and Surgery al., 2009; McDowell et al., 2014). Certain models have been developed to predict behaviour in specific scenarios under specific constraints, but these generally represent the standard human behaviour and do not or rarely predict the probable variability found across the population (Ajzen, 1991). Specifically, the developmental background and cognitive-behavioural repertoire of an individual human, are not adequately taken in account in these models (McDowell et al., 2014). Consequently, the behaviour of an individual in a specific context cannot be accurately predicted. Thus, if specific knowledge of an individuals' behaviour within the context is needed, but is not accurately predictable, it becomes extremely difficult to incorporate robotic technologies with humans in a social context (Alami et al., 2006; McDowell et al., 2014). However, sensing advancements in robotics offers solutions combining computational and data mining approaches that allows research advances towards understanding and integrating interactions between psychological, physiological and behavioural variables that represent the human state. For instance, using similar approaches, researchers have demonstrated advances in automation adapting a relationship between human and robot (Wada et al., 2004; McDowell et al., 2014). Although artificial intelligence, cognitive science, neuroscience and robotics, have different perspectives in its research, all contribute to the understanding of human minds (Liard et al., 2017). Powerful modern artificial intelligence involves building artificial minds along with systems exhibiting intelligent behaviour. Cognitive science involves shaping natural minds with the understanding of cognitive processes generating human thoughts (Liard et al., 2017; Cross & Ramsey, 2021). Neuroscience involves the structure and function of the brain hence concerning how brains give rise to minds. Robotics involves the building and controlling of artificial structures, and thus concerns how minds control such structures (Gallagher, 2006; Liard et al., 2017). Therefore, the integration of 4 Advancement of Robotics in Healthcare, Medicine and Surgery human body with robotic technologies helps to make the human-robot interaction stronger and build robotic technologies with unique information sources that may ultimately provide benefits over human-human interactions (Cross et al., 2019). Humanoid robots in this way prove to be advantageous for understanding human cognition and human cognitive development due to their physical embodied presence as well as options for experimental control. They are just not assistants and associates to humans in different spheres, they can even be engaged as sophisticated stimuli for studying socio-cognitive phenomena in humans, can inform us about actual specific elements of humanness and can generate novel theoretical predictions about the workings of the human brain (Wykowska 2021).

ROBOTIC TECHNOLOGIES IN HEALTHCARE AND MEDICAL SCIENCES

During 1980s, robotic technology paved way into healthcare industry (Kujat, 2010). According to DESTEP approach by Fahey and Narayanan (1986), there are six major factors that influence the development of robotics in healthcare and medical science domain viz., demography, economy, society, technology, environment and politics. As development synergises value addition, in consequence, robotic systems benefits health care and medical sciences through labour cost reduction, increased individual independence and self-support in daily life, enhancing the quality of care and performing actions that no human being can achieve (Table 4). The applicability, accessibility, availability and affordability of robots in healthcare and medical sciences with effective outcomes can only be achieved through adequate personalization, proper levels of autonomy, increased work efficiency, appropriate navigation, object manipulation, user safety, low production costs and proper integration of the Internet of Things (IoT) platform (Al-Razgan et al., 2016; Aggarwal et al., 2019). Artificial intelligence (AI) algorithms employed knowledge-based methods to create unique opportunities to 5 Advancement of Robotics in Healthcare, Medicine and Surgery enhance clinical practice. Their employment has been tested at every stage of prognosis to improve treatment approaches and rehabilitation. The increased levels of automation in robots provide good levels of precision for various medical tasks viz., disinfection, communicating with isolated/infectious patients, lifting the patients, phlebotomy, stock maintenance, pharmacy workforce, etc (Awad et al., 2021). As a result of this, large centralised/decentralised robots are being employed in hospitals and pharmacies to accelerate medication stocking, storing and picking as well as managing stocks, tracking and distributing medication to the patients (Purkiss 2007). Besides, small biodegradable robots such as microrobots/nanorobots are being remotely monitored for accurate in vivo drug delivery to targeted disease sites, for internal wound closures or for elimination of exogenous substances from within the body. All these advancements are possible due to 4D printing, which is an ultra-advance manufacturing technology with the utilization of smart materials that has made remarkable progress where 3D printed robot models are designed as programmable tools with abilities to respond to varied stimuli (Joyee and Pan, 2020). Patients with physical impairments/rehabilitation patients are provided services and physical assistance through assistive robots/autonomous robots/personal care robots/carebots (Fosch-Villaronga and Ozcan, 2020). Some of such robots in trend now a days are prosthetic limbs for ambulation as well as exo-/endo-skeletons that serve as wearable devices to substitute for/improve the functionality of patient’s limbs. For superior rehabilitation outcomes, these robots are employed for efficient training of physically impaired/rehabilitation patients along with quantitative feedbacks to the patients (Chen et al., 2013). With the dearth in skilled nursing staff, nursing robots proved to be a promising innovation in robotic technology that egressed as an alternative with assistive robots to perform autonomously in healthcare environments. However, these nursing robots are required to perform work or be used in unification with human nurses. 6 Advancement of Robotics in Healthcare, Medicine and Surgery Nursing robots are specifically designed and programmed to mimic the morphology and communicating abilities of human nurses. The major targeted deployment locations of assistive nursing robots are home and living centers having ageing population (Carter- Templeton et al., 2018; Maalouf et al., 2018; Anghel et al., 2020; Frith 2021; Fernandes and Bijlee, 2022). The worldwide pandemic era of COVID-19 has witnessed very efficient utilization of aerial robots (drones) for distribution of necessary medical supplies in the interior rural communities and remote areas, globally. Not only this, but drones also aerially transported pathological specimen/samples to centralized testing facilities within no time, which helped medical practitioners make rapid treatment decisions and improve patient health conditions (Sham et al., 2022).

ROBOTIC TECHNOLOGIES IN SURGERY

The integration of neuroscience with robotic technologies aims towards understanding interactions between psychological, physiological and behavioural variables that represent human state through the use of robotic technologies (McDowell et al., 2014). Technological developments and their interventions in imaging guidance, intraoperative imaging and microscopy have pushed neurosurgeons to the limits of their competence and stamina. Due to these attributes associated with robotic systems, they are now considered as an epitome of the future of surgery. The introduction of robotically assisted surgery has provided surgeons with improved ergonomics and enhanced visualisation, dexterity and haptic capabilities (Table 5). The first application of robotic-assisted surgery was in the neurosurgical field but robotic advancements in urology, gynaecology, gastroenterology and orthopaedics are more common due to fewer anatomical challenges. For example, a large cavity where a robotic arm could be used to assist in spine surgery is non-existent and brain surgery involves 7 Advancement of Robotics in Healthcare, Medicine and Surgery delicate neural structures and approaches through narrow surgical corridors where manipulation and space are both limited. (Doulgeris et al., 2015). The first neurosurgical robots relied on preoperative images to determine robotic positioning. As a result, surgeons could not dynamically monitor needle placement under image-guidance and were blind to changes such as brain shift. To satisfy the need for a real-time, image-guided system, Minerva was developed. The system consisted of a robotic arm placed inside a computed tomography (CT) scanner, thus allowing surgeons to monitor the operation in real-time and make appropriate adjustments to the trajectory as needed (Paul B. et al., 2004; Burckhardt et al., 1995).

Different Robots used in Neuroscience

Robot	Year of discovery	Researchers involved in the discover	Technology used	Advancements made to introduce it to human system	Applications and uses	Reference

		y				
Programmable Universal Machine for Assembly (PUMA 200)	1985	Kwoh et al	It uses computed tomography and Stereotaxic operations in the brain surgery which is a technique that involves guiding the tip of a probe or other sensitive surgical tool into the brain through a small burr hole created in the skull without direct view of the operative site.	The surgeries were performed with a Brown-RobertWells stereotactic frame secured to the same rigid structure as the robot, providing accurate transformation from the stereotactic coordinate frame to the robot coordinate frame.	The PUMA 200, designed to be extremely adaptable, its computer is compatible with a wide range of imaging computers now in use in the biomedical industry. The PUMA 200 robot is safe because it has spring-applied, solenoid-released brakes on the waist, shoulder, and elbow joints that immediately clamp in the event of a mechanical or electrical failure.	29
Neuromate	1987	Grenoble University of Benabid and colleagues	The computer houses software for the control of robotic movement, the registration process and stereotactic planning. It has been designed for use in stereotactic neurosurgery and its use in conjunction with conventional stereotactic localizer frames	A single base plate is implanted into the skull under local anaesthesia and during imaging the detachable fourspoked fiducial system, which has MRI- and CT-visible markers at the end of each spoke, is mounted to the base plate. The area covered by the imaging includes the	This 6 degrees-of-freedom (DOF) robot was used to position the brain cannula on the basis of coordinates from 3D imaging data. The system has been used in over 1000 tumour biopsies, 200 investigations of patients with epilepsy, and 200 cases of functional neurosurgery for	30

				surgical target and the fiducial markers	movement disorders. Spatially encoded data from radiograph, CT, MRI, or angiography were used to locate the lesion. neuromate can be used for several neurological applications, including deep brain stimulation, endoscopy, and stereo encephalography, and it is an efficient and safe instrument for biopsies in clinical cases.	
Minerva	1993	Glauser et al	It uses visualisation software developed to allow operation planning and reconstruction of various planes. It is linked to interface software used to pilot the operation. Additional software has been developed to compute the transforms between the robot's coordinate system, the scanner's coordinate system, and a reference coordinate	The mechanical structure of the Minerva robot system is adapted to satisfy the sterilisation constraints, the requirements for dynamic properties in surgical operations, and, most importantly, the safety requirements. Because of mechanical inaccuracy and misalignment, calibration software is needed to reach a point	It is used in Stereotactic surgery which is usually performed through a 2 mm hole drilled in the skull. This small opening precludes any direct visual control of the operation, and small probes are advanced to a target within the brain, previously located on computed tomography (CT) images	31

			system linked to the patient's head. All instruments are considered as separate robot degrees of freedom. They have been developed as mechanical and electronic entities, including specific control parameters and an interventional procedure during surgery.	defined in the robot's coordinate frame but measured on the CT scanner images		
RAMS	1997	Kozlowski et al	The mechanical subsystem is a cable-driven slave arm with 6 DOF. The arm (25 cm long, 2.5 cm in diameter) is mounted to a cylindrical base, providing a work envelope greater than 400 cc. Its positional accuracy is 10 microns. The hand controller also has six cable-driven joints with force feedback capability.	RAMS has the potential to be teleoperated, despite the absence of remote visual feedback. RAMS has adjustable tremor filters and motion scalers to enhance dexterity.	The RAMS robot has been used in microvascular anastomosis in neurosurgery. Carotid arteriotomies have also been performed which then subsequently were closed with suture by surgeons, students, engineers, or even RAMS. RAMS was superior to the students and engineers and as effective as the surgeons, but took over twice the time to complete the procedure.	33

Da Vinci Surgical Robot System	2000	Intuitive Surgical	The Da Vinci System consists of a surgeon's console that is typically in the same room as the patient, and a patient-side cart with three to four interactive robotic arms controlled from the console. The arms hold objects, and can act as scalpels, scissors, or graspers. The final arm controls the 3D cameras. The surgeon uses the controls of the console to manoeuvre the patient-side cart's robotic arms. The system always requires a human operation.	The Da Vinci System has reduced risk of infection or complications. Less scarring because of smaller incisions and fewer sutures. Briefer hospital stays/faster recovery. More rapid return to normal activities, including urinary continence, sexual function, and more.	The DaVinci Surgery system is a series of tiny highly dexterous robot arms that can be manipulated by a qualified surgeon to complete precise cutting and stitching. During the surgery, the surgeon sits at a console and views the patient's target anatomy in a high definition 3D image. The surgeon can deftly manipulate the robotic arms through movement of their own hands and wrists. The advantage of getting the robots to actually complete the work is their ability for absolute, precision, control and flexibility. The surgery can be used on a range of minimally invasive surgeries such as cardiac, urologic including prostate, bladder and kidney cancers, and thoracic surgery.	32
Tug	2004	Aethon	TUG houses some	-	It can be used to deliver	34

			sophisticated technology under the hood. Multiple sensors, including sonar, infrared and a SICK laser scanner, help it navigate autonomously and safely among its biped coworkers and hospital visitors.		medications, laboratory specimens, or other sensitive material within a hospital environment. TUG can navigate using a built-in map and an array of on-board sensors. Additionally, it uses Wi-Fi to communicate with elevators, automatic doors, and fire alarms.	
Hybrid Assistive Limb (HAL)	2011	Cyberdyne	When a person attempts to move their body, nerve signals are sent from the brain to the muscles through the motor neurons, moving the musculoskeletal system. When this happens, small biosignals can be detected on the surface of the skin. The HAL suit registers these signals through a sensor attached to the skin of the wearer. Based on the signals obtained, the power unit moves the joint to	-	HAL is mainly used by disabled patients in hospitals, and can be modified so that patients can use it for longer-term rehabilitation. In addition, scientific studies have shown that, in combination with specially-created therapeutic games, powered exoskeletons like the HAL can stimulate cognitive activities and help disabled children walk while playing. HAL Therapy can be effectively used for rehabilitation after spinal	35

			support and amplify the wearer's motion.		cord injury or stroke	
3D Brain Function Mapping	2017	MIT	The vanguard technique combines third-harmonic generation (THG) three-photon microscopy with retinotopic mapping, allowing activity to be observed through deep brain tissue via electrical signatures. It also delivers stunning resolution, allowing individual neurons and their substructures to be studied, as well as fine blood vessels and myelin – a kind of insulator known to be a critical factor in brain processing speed.	-	It is generally used to study the visual centres of the brain, and can be used to study other regions. It promises to be a powerful tool for understanding differences in healthy and diseased brain states, as well as how the brain responds to environmental stimulation.	36
Stentrode™	2020	Thomas Oxley	The implant uses wireless technology to relay specific neuronal activity into a computer, where it is	Stentrode™ is inserted through keyhole surgery into the neck, and from then moved into the motor cortex	The minimally invasive nature of the treatment shows the great potential for micro neurotechnologies to	37

			converted into actions based on the intentions of the patients. Amazingly, this tiny chip allowed the patients to perform actions like click and zoom, and write with 93% accuracy, helping them do things we take for granted like text, email and shop online.	via blood vessels. This minimally invasive method avoids the associated risks and recovery complications of open brain surgery.	help aid people with all kinds of cognitive impairments.	

INTERNET OF THINGS (IOT) AND INTELLIGENT ROBOTS

The evolution of Internet of Things (IoT) emerged by the new advancements in the silicon and sensors technologies where distributed sensing systems connected to a cloud computing server establish extremely intelligent algorithms to monitor and interact with humans. These advances in the technology enabling the development of intelligent robots, is also aiding the neuroscience sector (Khan et al., 2020). For example, novel applications are actively being developed in which applications such as brain interfaces control machines and individualised assessment of mental wellness and disease. The use of brain activity and body signals as feedback to enhance human work performance is one emerging application. This is called the field of neuroergonomics (Ayaz &Dehais, 2018). Portable brain and physiological signal acquisition systems track mental activity and performance in a variety of tasks and situations, with algorithms analysing the data to produce work and mental performance metrics. This is very useful for researchers as they can use the data to rethink tasks and work settings in order to increase human productivity and efficiency (Sawangjai et al., 2019; Baig&Kavakli, 2019). 8 Advancement of Robotics in Healthcare, Medicine and Surgery

CONCLUSION

In the past two decades, robotics has evolved immensely with increased prospects in biological, healthcare, medicine and surgery industry. Robots are being used in almost everything and almost everywhere. However, they are not to replace qualified human workforce, instead, assist them in routine work and precision tasks to achieve high throughput. Advancements in micro- and nano-robotic devices is very much dependent on innovations in micro-electro-mechanical systems (MEMS) and nano-electromechanical systems (NEMS) with collaborations among diverse domains of research viz., life science, medicine/surgery and engineering. From robot-assisted surgeries to robots helping humans recover from injury as well as their utilization in physical therapy are the notable models of robot existence. However, despite this future vision, there is little evidence that such robots will exist any time soon. First, in technological terms, autonomous, humanoid robots are nowhere near ready for use in care or other real-world settings involving (physical) contact with people. Second, there is currently little demand for genuine care work done by robots. Neither caregivers nor care recipients have expressed explicit interest in robotic applications. Scenarios proposing this are usually rejected. However, there are many doubts about the broader ethical and legal issues around using robots for care.

Table 1: Classification of industrial robot's applications based on industry type. {Courtesy: International Federation of Robotics (IFR) industry classification and International Standard Industrial Classification of All Economic Activities (ISIC) revision 4} (Jurkat et al., 2021).

Parent Class Title	Sub-Class	Manufacture of
Agriculture, forestry, and fishing	--	--
Mining and quarrying	--	--
Manufacturing	Food and beverages	Food products; beverages; tobacco products
	Textiles	Textiles; wearing apparel; leather and related products
	Wood and furniture	Products of wood and cork; articles of straw and plaiting materials; furniture
	Paper	Paper and paper products; printing and reproduction of recorded media
	Pharmaceuticals, cosmetics	Pharmaceuticals, medicinal chemical and botanical products; soap and detergents, cleaning and polishing preparations, perfumes and toilet paper
	Rubber and plastic products (AutoParts)	Manufacture of rubber and plastics products
	Rubber and plastic products (non-automotive)	
	Other chemical products	Coke and refined petroleum products; chemicals and chemical products
	Chemical products, unspecified	--

	Glass, ceramics, stone, and mineral products (non-automotive)	Other nonmetallic mineral products
	Glass (AutoParts)	
	Metal	--
	a) Basic metals	Basic metals
	b) Metal products (non-automotive)	Fabricated metal products, except machinery and equipment
	c) Industrial machinery	Machinery and equipment
	d) Metal, unspecified	--
	Electrical/electronics	Computer, electronic, and optical products; electrical equipment
	a) Household/domestic appliances	Domestic appliances
	b) Electrical machinery (non-automotive)	Electric motors, generators, transformers and electricity distribution and control apparatus; batteries and accumulators; wiring and wiring devices; electric lighting equipment
	c) Electronic components/devices	Electronic components and boards
	d) Semiconductors, LCD and LED	
	e) Computers and peripheral equipment	Computers and peripheral equipment; magnetic and optical media
	f) Info communication equipment domestic and professional (non-automotive)	Communication equipment; consumer electronics
	g) Medical, precision, and optical instruments	Measuring, testing, navigating, and control equipment; watches and clocks; irradiation, electromedical and electrotherapeutic equipment; optical instruments and photographic equipment
	h) Electrical/electronics, unspecified	Other electrical equipment
	Automotive	--
	a) Motor vehicles, engines, and bodies	Motor vehicles; bodies (coachwork) for motor vehicles; manufacture of trailers and semi-trailers
	b) Automotive parts	--
	i) Metal (AutoParts)	Parts and accessories for motor vehicles
	ii) Electrical/electronic (AutoParts)	
	iii) Other (AutoParts)	
	iv) Unspecified AutoParts	--
	c) Automotive unspecified	--

	Other vehicles	Other transport equipment
	All other manufacturing branches	Machinery and equipment manufacturing, repair and installation
Electricity, gas, and water supply	Electricity, gas, steam, and air conditioning supply	--
	Water collection, treatment, and supply; Sewerage	--
	Waste collection, treatment, and disposal activities; materials recovery	--
	Remediation activities and other waste management services	--
Construction	Construction of buildings; Civil engineering	--
	Specialized construction activities	--
Education/research/development	Education, Scientific research and development	--
Other nonmanufacturing branches not specified above	Wholesale and retail trade; repair of motor vehicles and motorcycles	--
	Transportation and storage	--
	Accommodation and food service activities	--
	Information and communication	--
	Financial and insurance activities; Real estate activities	--
	Professional, scientific, and technical activities (without scientific research and development)	--
	Administrative and support service activities	--
	Public administration and defence; compulsory social security	--
	Human health and social work activities	--
	Arts, entertainment and recreation	--
	Activities of households as employers; undifferentiated goods- and services producing activities of households for own use	--
	Activities of extraterritorial organizations and bodies	--

References

Brooks, R. (1999) Cambrian intelligence : The early history of the new AI. The MIT Press, Cambridge, MA, 1999.

Dautenhahn, K. (2002) Design spaces and niche spaces of believe social robots in Proceedings of IEEE Int. Workshop on Robot and Human Interaction Communication ROMAN 2002. p. 192-197, IEEE Press. [Dautenhahn and te Boekhorst 2005] Dautenhahn, K. and te

Boekhorst, R. (eds) (2005) Proceedings of the Symposium on Robot Companions: Hard Problems and Open Challenges in Robot-Human Interaction, AISB05 Convention. [Freud 1985]

Freud, S. (1985) L'inquiétanteétrangeté et autresessais. Folios essais, p.213-263. [Kaplan 2001]

Kaplan, F., (2001) la naissance d'une langue chez les robots, Hermès Science [Kaplan 2004]

Kaplan, F. (2004) Who is afraid of the humanoid? Investigating cultural differences in the acceptance of robots, International Journal of Humanoid Robotics, 1(3):465-480. [Kaplan 2005] Kaplan, F. (2005) Les machines apprivoisées: comprendre les robots de loisir, Vuibert. [Norman 1988]

Norman, D. (1988) The design of everyday things. Doubleday. [Hall 1966] Hall, E. (1966) The Hidden dimension. Garden City, Doubleday.

Hamblen, J.O., &Bekkum, G.M. (2013). An Embedded Systems Laboratory to Support Rapid Prototyping of Robotics and the Internet of Things. IEEE Transactions on Education, 56, 121-128. 8.

Aguilar, J., Zhang, T., Qian, F., Kingsbury, M., McInroe, B., Mazouchova, N., Li, C., Maladen, R.D.,

Gong, C., Travers, M.J., Hatton, R.L., Choset, H., Umbanhowar, P., & Goldman, D.I. (2016). A review on locomotion robophysics: the study of movement at the intersection of robotics, soft matter and dynamical systems. Reports on progress in physics. Physical Society, 79 11, 110001.

Chiolerio, A., &Quadrelli, M. (2017). Smart Fluid Systems: The Advent of Autonomous Liquid Robotics. Advanced Science

Krishnan, R.H., &Pugazhenthi, S. (2014). Mobility assistive devices and self-transfer robotic systems for elderly, a review. Intelligent Service Robotics, 7, 37-49.

Rahul Reddy Nadikattu. 2016 THE EMERGING ROLE OF ARTIFICIAL INTELLIGENCE IN MODERN SOCIETY. International Journal of Creative Research Thoughts. 4, 4 ,906-911. 12.

Rahul Reddy Nadikattu, 2014. Content analysis of American & Indian Comics on Instagram using Machine learning", International Journal of Creative Research Thoughts (IJCRT), ISSN:2320-2882, Volume.2, Issue 3, pp.86-103.