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A Glimpse into Artificial Intelligence in Animal Physiology and Allied Sciences

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ABSTRACT

Artificial Intelligence (AI) has developed as an interdisciplinary science based on computers and is concerned with building machines and equipment which use human intelligence to perform a particular task. The role of AI is manifold in our day-to-day lives. With high penetration amongst people in different societies, AI has transformed the way of living and has the potential to act as a vehicle to disseminate information regarding animal health, production, and reproduction aspects. AI has already made an immense contribution in veterinary and allied sciences by helping in devising various applications used in research and simulation aids. In addition, it has been put in to use efficiently in the field of veterinary sciences thereby hastening diagnosis, treatment, and prognosis of various animal diseases. The history of AI, its applications as software packages in statistics, bioinformatics, simulation apps, and a list of various equipment used for analytical, clinical, and livestock farm purposes are elaborated in this article. Despite playing a vital role, AI has to be further refined in such a way to target the rural livestock farmers to improve animal health and production in developing countries that are in dire need of meeting food security requirements amidst the current scenario of population explosion.

Introduction

Intelligence is defined as the ability to acquire and apply skills and knowledge. It relates to brainpower. How quickly, efficiently, and also how an animal tackles a problem or adverse/favorable situation in its day-to-day life will define its intelligence and mental ability. Intelligence involves judgment, reasoning, understanding, acumen, insight, comprehension, sharpness, alertness, acuity, and also intuition. It is a physiological trait present in varying degrees in different animals.

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Artificial Intelligence (AI) is using the intelligence (brainpower) of human beings to construct and run machines that are smart i.e. make machines do the work that humans need to do, but with greater precision, specificity, efficiency, and quickly. Ever since the time humans invented the wheel, the wheels of scientific inventions and the development of machines have been turning at a faster rate much ahead of their time. Robotics has made medical science so advanced that the question now arises if robots will replace humans as doctors. The authors attempt to review the literature and probe into AI in the field of physiology and animal sciences.

Cognitive learning and information processing are the two crucial functions performed in various parts of the brain such as the cortex, basal ganglia, thalamus, and cerebellum. The information processes thereby performed govern the neuron physiology (Coward, 2011). Gardner (1983), the American development psychologist classified intelligence, based on the soft skills possessed by humans (Table 1).

Development of artificial intelligence

AI has developed as an interdisciplinary science based on computers and is concerned with building machines and equipment which use human intelligence to perform a particular task (Table 2). It may have multiple approaches to a task (Anonymous, 2021) involving the cognitive function and performance level of the human brain. Medicine and machine learning (ML) together have the potential to transform healthcare. Physiology, being a foundational discipline with rich quantitative history plays a vital role in medical training and practice, has the potential to yield a template of a common language that can be useful for both the clinicians and ML experts and in accentuating an impact on human health (Sarma et al., 2020). AI has become an integral part of our lives and its involvement has evolved veterinary science for quick diagnosis, treatment, and management of animals.

The application of AI in animal physiology and health care is manifold. An attempt is made here to list out briefly the areas where it is utilized (Table 3).

Table 1: Classification of human intelligence based on the soft skills

SOFT SKILL	TYPE OF INTELLIGENCE
Nature smart	Naturalist
Sound smart	Musical
Number / Reasoning smart	Logical-Mathematical
Life smart	Existential
People smart	Interpersonal
Self-smart	Intrapersonal
Body smart	Bodily-Kinesthetic
Word smart	Linguistic
Picture smart	Spatial

Table 2: Timeline of the evolution of AI

Year	Scientist / Originator	Event published/discovered or happened	Remarks
1943	Warren McCullough and Walter Pitts	Published paper "A logical calculus of ideas immanent in nervous activity."	Proposed the first mathematic model for building a neural network
1949	Donald O. Hebb	Proposed the theory that experiences generate neural pathways and become stronger when frequently used. Published book "The organization of behavior: A neuropsychological theory"	An important model in AI and frequently referred to as Hebbian learning.
1950	Alan Turing	Published "Computing machinery and intelligence"	Proposed the Turing test, based upon which a machine can be classified as intelligent
	Marvin Minsky and Dean Edmonds	Built spatial-numerical association of response codes (SNARC)	The first neural network computer
	Claude Shannon	Published paper "Programming a computer for playing chess"	---
	Isaac Asimov	Published "Three laws of robotics"	---

(Table continued)

(Table continued)

1952	Arthur Samuel	Developed a program featuring self-learning ability to play checkers	---
1956	John McCarthy	Coined the phrase AI at the “Dartmouth summer research project on AI”	The scope and goals of AI are outlined, widely recognized as the birth of AI
	Allen Newell and Herbert Simon	Demonstrated logic theorist (LT), the first reasoning program	---
1958	John McCarthy	Developed lisp, an AI programming language, and published the paper “Programs with common sense”	Proposed an AI system that can learn from prior experiences with an efficiency that is comparable to humans
1959	Allen Newell, Herbert Simon, and J.C. Shaw	Designed general problem solver (GPS), a program that features problem-solving capacity displayed by humans	---
	Arthur Samuel	First to use the term machine learning at international business machines (IBM)	---
	John McCarthy and Marvin Minsky	Found the Massachusetts institute of technology (MIT) AI Project	---
1963	John McCarthy	Started the AI lab at Stanford, CA, USA	---
1969	Edward Feigenbaum, Bruce G. Buchanan, Joshua Lederberg, and Carl Djerassi, along with a team at Stanford, CA, USA	Designed expert systems like DENDRAL, a XX program, and MYCIN, useful in diagnosing blood infections	---
1972	Alain Colmerauer and Robert Kowalski	PROLOG, the first-ever logical programming is created	---
1973	James Lighthill	The Lighthill report on “Artificial Intelligence: A general survey” published	It detailed the disappointments in AI research
1974 -1980	---	Disappointment with the progress of development in AI along with previous reports had led to the temporary stalling of research	The period is widely regarded as “First AI Winter”
1980	John P. McDermott of Carnegie Mellon University (CMU) and Digital Equipment Corporation (DEC)	Developed R1, a commercial expert system that helps in configuring orders for new computer systems and initiated an investment boom	Brought an end to the 1st ‘AI Winter’
1982	Japan’s Ministry of International Trade and Industry	Fifth generation computer systems (FGCS) project is launched	Developing a supercomputer-like performance and platform for AI development were outlined as major goals of this project
1983	The U.S. government	Launched the strategic computing initiative.	Funded research in the niche areas of advanced computing and artificial intelligence through the defense advanced research projects agency (DARPA)
1987-1993	Improving computer technologies	The Lisp machine market collapsed in 1987 with the advent of cheaper alternatives. Japan terminated the FGCS project in 1992 and DARPA ended the Strategic Computing Initiative in 1993 as it fell short of expectations despite heavy expenditure.	The phase was considered as “Second AI Winter”
1991	U.S. Military Forces in collaboration with BBN systems & technologies the ISX Corporation	Deployed dynamic analysis and replanning tool (DART), an automated logistics planning and scheduling tool.	DART was used during the beginning of operation desert storm the Gulf War

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1997	IBM's Deep Blue	Defeated world chess champion Gary Kasparov.	---
2005	Created by Boston Dynamics with Foster-Miller, the NASA jet propulsion laboratory, and Harvard university concord field station	Introduced an autonomous robot like Boston dynamic's "Big Dog" a robotic pack mule and iRobot's "PackBot".	For bomb disposal, hazmat, search, reconnaissance, and other dangerous missions.
2008	Google App	Made breakthrough in speech recognition.	Introduced the feature in its iPhone app
2011	IBM Watson	Designed a computer system with the ability to answer questions on Jeopardy	Won the first prize on Jeopardy by competing against champions
2012	Andrew Ng, founder of the Google Brain Deep Learning project	Deep learning algorithms were used to feed a neural network	Recognized as a period of breakthrough for funding in neural networks and deep learning
2014	Google co.	Invented the car with a self-driving ability which had also cleared the state driving test at Sans Francisco	Later named "Waymo" - a new way forward in mobility
2015	Google Deepmind	Achieved human parity by playing 29 Atari games.	Learned general control from video
2016	Google co.	Google deep mind's alphaGo (a board game) and sets a record by defeating Lee Sedol	The major hurdle to AI in clearing the ancient Chinese game is attributed to its complexity
2020	Created by Open AI, a San Francisco-based AI research laboratory	Designed a language model using deep learning to generate human-like text, commonly known as generative pre-trained transformer 3 (GPT3)	Categorized in the GPT-n series as a third-generation language prediction model
	Google's DeepMind	Developed alphafold 2 - an AI program that predicts protein structure	Led to disease understanding and the medicine to be developed

Table 3: Applications of AI in Animal and allied sciences

Area	AI utilized for
Teaching	• Simulators for the study of physiological functions of different systems, anatomical structures, and dissection, clinical medicine
Research and development	• Development of drugs • Simulators to study the effect of drugs • Vaccine development • Packaging and delivery of drugs • Efficacy and half-life of a drug • Biological potency and shelf life of drug • Digital balances and weighing machines • Automatic inoculators
Treatment	• Tele-medicine (consultation, diagnosis, and advice)
Survey and mapping	• Radio tagging of animals and birds (collars, implants) • Drones fitted with digital cameras
Farm management	• Drones (surveillance, water management, spraying of pesticides) • Milking machines, rotary milking parlor • Infrared thermal imaging sensors • Pedometers • Facial recognition machine visual sensors • Species related application (cattle, sheep, goat, horse, swine, poultry) • Prediction of animal behavior through accelerometers, magnetometers (Dutta et al., 2015), optical sensors (Pegorini et al., 2015), or depth video cameras (Matthews et al., 2017) • Sheep pain facial expression scale (SPFES), aids in assessing pain and discomfort in sheep (McLennan et al., 2016) • Sensors that help estrus detection (Riaboff et al., 2020) • A machine can help estimate milk yield (Gianola et al., 2011), Reproductive performance (Shahinfar et al., 2014), calving time (Brochers et al., 2017) • Detection of mastitis through somatic cell count (Dhoble et al., 2019)

(Table continued)

Agriculture	• Autonomous tractors (self-driven) • Robotic machines that control unwanted crops or weeds harvest crops with greater speed, help in picking and packing crops • Pest (grasshoppers, locusts) control through satellite and smartphones • Bailing of straw and hay • Identifying defects and nutrient deficiencies in soil (soil analysis) • Identifying plant pests and diseases • Detect defects in plants (by using image recognition-based technology) • Drone-based aerial imaging technique to monitor plant health, guide farmers regarding optimum planting and management of plants (precision farming) (Bisen, 2019)
Meteorology	• Weather forecasting • Disaster management (cyclones, tsunamis, heavy rainfall and floods, cloud bursts, draught, and famine)
Personal animal details	• Micro-chip implants (placed under animal skin and uses radiofrequency) and scanners,
Disease prevention	• Includes sensors, big data, and machine learning which have an immense contribution in devising cost-effective and non-invasive manners to predict and prevent several diseases (Neethirajan, 2020).
Data Analytical Software	• Various software is listed below for data recording, storage, and analysis

Data analytical software used in veterinary science indicated in Table 4.

Table 4: List of data analysis software tools used in veterinary science

Name of software	Veterinary medicine and clinical management software
IDEXX, cornerstone vet software (AAHA)	Health network, data backup, payment portal
AVImark, Henry Schein vet solution	Electronic medical records, patient reminders dental charts, support paperless practices
IntraVet	Clinical services
Vetter	Electronic vet record tool that allows you to see consolidated patient record
eVetPractice	Electronic medical records
DVMAX	Practice management
Hippo manager software	Clinical appointments, reminders, SMS
ezyVet	Next generation in cloud-based practice management software
Equine Gait trax / canine gait trax	Motion analysis software (2D and 3D)
DMAS-6 and DMAS-DV motion capture suits	Motion analysis software (2D and 3D)
EMPRES-i	Information system designed by FAO on global animal diseases
Winepiscope 2.0	Epidemiological veterinary medicine software
VETport	Cloud-based practice management software for veterinary clinics
Casado Equine	A user-friendly software tool to document medical records and billing that is mainly useful for Solo Equine veterinarians
Qvet, VeterinaryGate Advanced, Bastet Win, Animal Hospital Management System, VxWorks, IntraVet	Veterinary practice management software

Some of the software used for image analysis of cells, tissues, and microbes (Table 5), for data analysis in statistics (Table 6), and bioinformatics (Table 7) are tabulated with their applications.

Table 5: Software tools used for image analysis

Name of software	Image analysis for cells, tissues, microbes
QuPath, Cell profiler, Ilastik, Orbit, Icy	Image analysis software for cell and tissues
CellSens for deconvolution, automated high-content analyses, and quantitative image analyses	
AutoQuant for deconvolution and quantitative image analyses	
Imaris for 3D rendering and quantitative image analyses	
ImageJ / Fiji	For micrometry of cells

Table 6: Software tools used for data analysis

Name of software	Data analysis
SPSS 27.0 (IBM), GraphPad Prism 9.0, statistical analysis software (SAS)	General Statistical analysis
Stata, JMP, OriginPro, Minitab 18, Scilab, TIMi Suite, GNU Octave.	
R (R foundation for statistical computing), MATLAB (The Mathworks), Microsoft Excel, MaxStat Lite, GenStat, MaxStat Pro, NCSS	
intrinsic Noise analyser (iNA)	Analyses fluctuations of intrinsic origin in various biochemical systems
Neurophysiological biomarker toolbox	A data-mining neurophysiological biomarkers toolbox that uses Matlab
Plotinus	Process raw data to generate graphs of various types
Slim fit	A simulation tool that performs statistics, curve fitting, and plotting
Chronux	For neurobiological time series data
Analytica	Visual analytics and statistics package
Genedata	A software tool that helps in integrating cum interpreting experimental data generated from research in Life Science R&D
MedCalc	For biomedical sciences

Table 7: Software tools used in bioinformatics

Name of software	Bioinformatics software
NET Bio	Microsoft 4.0 NET framework-based language-neutral toolkit for developers, researchers, and scientists globally
AMPHORA, Megan, Velvet assembler, GeneMark, UniFrac	Metagenomics analysis software
Ascalaph Designer	Performs molecular designing and simulation works in molecular modeling
BioJS	JavaScript library of components to visualize biological data
BioPHP	PHP language toolkit with classes for DNA and protein sequence analysis, alignment, database pairing, and other bioinformatics tools
GenGIS	An application that allows combining digital map data with information about biological sequences collected from the environment
GROMACS	Designed as a molecular dynamics package tool to produce simulations of proteins, lipids, and nucleic acids.
Mothur	Software tool for 16S rRNA gene analysis
PathVisio	Tool to draw, analyze, and visualize various biological pathways
SOAP Suite	Combination of tools for processing short-read next-generation sequencing data
Unipept	Meta-proteomics biodiversity analysis written in Ruby and JavaScript
TINKER	Molecular dynamics simulator that aids in deducing molecular mechanics and dynamics.
Abalone	Tool for simulations of bio-molecules
Genome Magician	Software for searching sequence motifs and alignment of paired sequences for NGS data (FASTA, FASTQ)
ALLALIGN	Sequence alignment tool featuring the ability to filter automatic repetitive sequences
BLAT and BLAST	Comparing the sequence similarity and alignment of gene sequences with genome

Various well-known veterinary practice management software like Qvet, VeterinaryGate Advanced, Bastet Win, Animal Hospital Management System, RxWorks, IntraVet, etc are commercially available across different developed countries. However, differences in data and reporting requirements limit their usage in Government veterinary hospitals in India.

AI is used in many of the instruments that we use routinely in laboratories, clinics, and farms. Though the list is very exhaustive, the authors have attempted to tabulate some of the commonly used equipment (Table 8 and 9).

Simulation refers to the artificial representation of actual processes to achieve education through experimental learning. The society for simulation in healthcare, termed simulation training as "the imitation or representation of one act or system by another" which serves as "a bridge between classroom learning and real-life clinical experience". A list of some simulators which are used in teaching and medicine are listed below (Table 10).

Table 8: List of microscopic and clinical imaging instruments

Microscope	Application
Stereo zoom microscope (3D)	Laryngoscope, Tracheoscope, Bronchoscope
Light Sheet Microscopy	Oesophagoscope
Scanning Transmission Electron Microscope (STEM)	Colonoscope
Electron Microscope	Vaginoscope
Dark Field microscope	Laparoscope
Fluorescent microscope	Proctoscope
Inverted microscope	Cystoscope
X-ray microscope	Arthroscope
Digital microscope	Otoscope

Table 9: List of clinical equipment and their application

Equipment	Application
Physiograph	Ultrasonograph
Spirograph	Echocardiograph
Electrocardiograph	Colour Doppler
Encephalograph	Boyles Apparatus
Retinograph	Electrosurgery unit
Kymograph	Cryosurgery unit
Bone densitometry / Dual Energy X-ray Absorptiometry (DEXA)	Perimetry (measurement of visual field function)
Mammography Machine	Digital X-ray machine
Resuscitator	Magnetic Resonance Imaging (MRI)
Estrous detector	Computed Tomography Scan (CT-Scan)
Oxygen Saturation Monitor	Nuclear Magnetic Resonance (NMR)

Artificial intelligence in simulators

Table 10: Simulation applications used in animal physiology and allied sciences

Simulation App	Utility	Remarks
SimNerv	Peripheral nerve physiology (frog)	Virtual physiology apps are available which help the student learn without actual animals and helps the student to understand and develop skills and ability to analyze www.virtual-physiology.com
SimMuscle	Isotonic, isometric contractions, fatigue in skeletal muscles (frog)	
SimNeuron	Basic neurophysiology experiments	
SimVessel	Smooth muscle of blood vessels (rat)	
SimHeart	Heart muscle and functions (rat)	
Cell and cell structure	Details about the cell	https://www.commonsense.org/education/top-picks/best-molecular-and-cell-biology-apps-and-websites
Cell strike	How immune system components work	
Learn Genetics	Understand complex genetic topics	
Portable	Periodic table details	
EteRNA	RNA structure and design	

(Table continued)

(Table continued)

Virtual Microscope	Detailed interactive animations that demonstrate the imaging techniques in SEM, Fluorescence Microscope (Light microscope), Atomic Force microscope	Imaging Technology Group, Beckman Institute for Advanced Science and Technology, University of Illinois http://virtual.itg.uiuc.edu/training/#animations
Simulations in rspiratory physiology, renal physiology, cardiovascular physiology, comparative vertebrate physiology, thermoregulation in hot and cold environments, endurance exercise, cardiac and (vascular) smooth muscle comparison, anemia, induction of fever and emphysema		Web-HUMAN physiology simulation version 4.0 https://norecopa.no/norina/web-human-physiology-simulation-version-40
Simulator for digital rectal examination, detect prostate cancer (Kuroda et al., 2005)		Haptic simulators – developed as a palpation-based simulator where touch is the primary sensation available to veterinarians (Baillie, 2007).
Virtual haptic back – for training osteopathic students (Williams et al., 2004)		
Haptic cow-for teaching bovine rectal palpation to identify pelvic structures, cervix, and uterus (SensAble Technologies, http://www.sensable.com.		
Horse ovary palpation simulator (HOPS)- number, shape, size of follicles can be felt and altered (Crossan, 2004)		
Farm animal related simulators		
Bovine Breeder™ Artificial Inseminator Simulator	Helps students to visualize the interior of the female reproductive tract and in learning appropriate methods of cervix manipulation, artificial insemination, and pregnancy diagnosis	
Bovine injection simulator	Teach all types of injections and infusions in different layers of skin and muscles	Reality works www.realityworks.com
Bovine milking udder simulator	Teach proper udder care, milk diseases, and infection treatment and prevention. Also, teach proper California mastitis test performance and udder anatomy	
Exercise physiology virtual lab	Supervise a clinical trial to investigate the acute and chronic physiological effects of high-intensity sprint interval training (SIT) on a sedentary lifestyle	The Labster https://www.labster.com/

Advantages of artificial intelligence in animal physiology and medicine

Physiology-based medical diagnosis systems are gaining importance in recent years, as they are reliable, accurate, and specific (Shuaib et al., 2020). Various physiological activities like respiratory, perspiratory, cardiovascular responses can be analyzed through thermal imaging channels (Thermography) without contact with the individual (Garbey et al., 2007; Pavlidis et al., 2012; Cho et al., 2019). The advent of AI has made diagnosis cheaper, faster, and easier and helped to recognize patterns of medical and veterinary complications (Suresh et al., 2019; Ahuja, 2019). It also helps to record and store medical information of the individual animal and other animals that have received treatment. Application to detect Addison's disease in canines was developed (Noah, 2020). Furthermore, diagnostic applications are developed which use hybrid AI (AI along with the experience of the veterinarian) to diagnose ailments through video recordings. Applications are also developed which suggest the diagnosis and treatment with veterinarians' notes as inputs. AI could help a farmer understand if his animal has an emergency and needs treatment. 'Smart Farms' can also be developed, which may automatically diagnose sickness and administer remedies/cures to the affected animal (as part of its feed), without any human involvement (Ishaq, 2020). It removes human bias in diagnosis and treatment, thus improving the skill and efficiency of veterinarians with the automation of tedious tasks on the farm. Simulators help in experimental learning in laboratories and classrooms without animals. However, AI cannot replace a veterinarian and only assists in accurate and speedy diagnosis and treatment.

Conclusion

Veterinary informatics can forge new possibilities within veterinary medicine and between veterinary medicine, human medicine, and One Health initiatives (Lustgarten et al., 2020). AI has made deep inroads into veterinary physiology and medicine. It has become an essential and irreplaceable component and helped evolve veterinary science. However, developing user-friendly AI technologies that reach livestock farmers thereby disseminating information about appropriate animal health practices, feeding practices, and management techniques shall be an imminent task in the future to improve the profitability of livestock rearing.

Competing Interest

None of authors have any conflict of interest.

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