



Artificial Intelligence in Pharmacy

Author Name: 1) Mr. ShindeVithal Sunil, 2) Proff. ShindePriyanka, 3) Dr. Megha Salve

Collage Name: shivajiraopawar collage of pharmacy pachegaon.
Department: Bachelor Of Pharmacy

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ABSTRACT

Artificial intelligence (AI) centers in creating cleverly demonstrating, which makes a difference in envisioning information, breaking issues and choice making. As of late, AI plays an critical part in different areas of drug store like medicate revelation, sedate conveyance definition improvement, polypharmacology, healing center drug store, etc. In medicate disclosure and sedate conveyance definition improvement, different Manufactured Neural Systems (ANNs) like Profound Neural Systems (DNNs) or Repetitive Neural Systems (RNNs) are being employed. A few executions of sedate revelation have right now been dissected and bolstered the control of the innovation in quantitative structure-property relationship (QSPR) or quantitative structure-activity relationship (QSAR). In expansion, de novo plan advances the development of altogether more up to date sedate atoms with respect to desired/optimal qualities. Within the current audit article, the employments of AI in drug store, particularly in medicate revelation, sedate conveyance detailing advancement, polypharmacology and healing center drug store are talked about

Key words: Artificial intelligence, Artificial neural network, Drug discovery, Drug delivery research, Hospital pharmacy.

I. INTRODUCTION

Artificial intelligence (AI) could be a stream of science related to shrewdly machine learning, mainly intelligent computer programs, which givescomes aboutwithin thecomparable way to human considerationhandle. This preparefor the most part comprises getting information, creating productive frameworks for the employments of gotteninformation, outliningpositive or surmised conclusions and self corrections/adjustments. In common, AI is utilized for analyzing the machine learning to mimic the cognitive assignments of people. AI technology is worked out to perform

more preciseexaminations as well as to achieve valuable translation.

In this point of view, different valuable measurable models as well as computational insights are combined within the AI innovation. The advance and advancement of AI applications are regularly related to the fear of unemployment danger. However, almost all progressions within the applications of AI innovation are being celebrated on account of the certainty, which massively contributes its efficacy to the industry. As of late, AI innovation gets to be an awfully essential portion of industry for the useful applications in numerous specialized and inquire about areas. The emanant activity of tolerating the applications of AI innovation in drug store counting medicate disclosure, medicate conveyance definition improvement and other healthcare applications have as of now been moved from buildup to trust. The employments of AI models moreover make conceivable to foresee the in vivo reactions, pharmacokinetic parameters of the therapeutics, appropriate dosing, etc. Concurring to the significance of pharmacokinetic forecast of drugs, the employments of in silico models encourage their viability and inexpensiveness within the medicate research. There are two key classes of AI innovation advancements. The primary one comprises the routine computing techniques counting master frameworks, which are competent of reenacting the human encounters and outlining the conclusions from the standards, like master frameworks. The moment one comprises the frameworks, which can demonstrate the mode of brain working utilizing the manufactured neural systems (ANNs). In particular, different ANNs like profound neural systems (DNNs) or repetitive neural systems (RNNs) control the advancements of AI innovation. In Merck Kaggle11 and NIH Tox21 challenge, DNN issues appear the more prominent predictivity than the pattern machine learning methodologies. The machine learning utilizes reasonable factual strategies with the

capability to memorize with or void of being unequivocally modified. In expansion, de novo plan advances the development of more current sedate particles with regard to optimal or wanted qualities. Within the current audit article, the employments of AI in drug store, particularly in medicate revelation, sedate conveyance definition improvement, polypharmacology and healing center drug store are talked about.

Milestones in Artificial Intelligence :

The primary utilize of the state- ‘Artificial Intelligence’ was showed up in 1956. Be that as it may, the concept of AI was utilized since 1950 with the employments of problem-solving as well as typical strategies.

Classification of AI

According to their ability, AI can be categorized as:

i) Artificial Narrow Intelligence (ANI) or Weak AI: It performs a narrow range task, i.e., facial identification, steering a car, practicing chess, traffic signalling, etc.

ii) Artificial General Intelligence (AGI) or Strong AI: It performs all the things as humans and also known as human level AI. It can simplify human intellectual abilities and able to do unfamiliar task.

iii) Artificial Super Intelligence (ASI): It is smarter than humans and has much more activity than humans drawing, mathematics, space, etc.

According to their presence and not yet present, AI can be classified as follows:

i) Type 1: It is used for narrow purpose applications, which cannot use past experiences as it has no memory system. It is known as reactive machine. There are some examples of this memory, such as a IBM chess program, which can recognize the checkers on the chess playing board and capable of making predictions.

ii) Type 2: It has limited memory system, which can apply the previous experiences for solving different problems. In automatic vehicles, this system is capable of making decisions there are some recorded observations, which are used to record further actions, but these records are not stored permanently.

iii) Type 3: It is based upon “Theory of Mind”. It means that the decisions that human beings make are impinged by their individual thinking, intentions and desires. This system is non-existing AI.

iv) Type 4: It has self-awareness, i.e., the sense of self and consciousness. This system is also non-existing AI.

Neural networks and ANNs

The learning algorithm of neural networks (from input data) takes two different forms mainly. The classes of neural networks are as follows (Figure 2):

i) Unsupervised learning: Here the neural network is submitted with input data having recognised pattern. It is used for organizational purpose. The unsupervised learning algorithm uses ‘Self Organizing Map’ or ‘Kohonen’. This is known as very useful modeling for the searching of relationships amongst the complex data sets.

ii) Supervised learning: This kind of neural network is illustrated with the sequences of harmonizing inputs and outputs. It is used for learning relationshipconnection between the inputs and the outputs. It shows its usefulness in formulation to measure the cause and effects linking between input-output. It is the most frequently employed ANNs and is entirely linked with the back propagation learning rule. This learning algorithm is known as the outstanding methodology for the prediction as well as classification jobs.

A straightforward scientific preparing unit called neuron is the most portion of the neural arrange. Each input has an related weight having relative significance and calculates the weighted entirety of all the inputs as yield. This yield is at that point sent to another neuron after being adjusted by a change work. The complete handling is called a perceptron (a feed-forward framework). A neural arrange having numerous neurons is organized into arrange designs. The foremost popular and affluent arrange is multilayer perceptron organize. In this organize framework, the indistinguishable neurons are orchestrated in such a way that in one layer, the outputs are displayed and within the consequent layer, the inputs are displayed. There are one or more mystery layers, which can be presented between the input and yield layers. In hypothesis, sum of mystery layers can be connected concurring to single require. In hone, numerous layers are required in case of applications with broad nonlinear conduct. ANN is one of the computational displaying figured from hundreds of single units of fake neurones related with the constituents comprising the neural structure, which are known

as handling components as they take an interest in data preparing.\

ANN strategy presents a potential modeling method, in specific for the information sets of non-linear joins commonly experienced within the pharmaceutical research.¹⁹⁻²¹ For the demonstrate determination examinations, ANNs don't require acquaintance of the information source. Be that as it may, they habitually have numerous weightages that ought to be analyzed. They too require bigger preparing sets. Also, ANNs can blend as well as include in both the writing and the investigational information to resolve the issues. As of late, ANN models are being hybridized with other sorts of easier models. For case, a as of late proposed combination of neural systems and calculated relapse permit the era of cross breed direct/ nonlinear classification surfaces and the distinguishing proof of conceivable solid intuitive that will exist between the attributes (also known as covariates within the Logistic Regression writing) which characterize the classification issue. All these cross breed models perform sensible well for a given set of databases. The planned employments of ANNs in drug store are widened from the information examinations by means of the modeling of pharmaceutical quality control. ANNs are moreover demonstrated utilitarian for the employments within the sedate planning, particularly in atomic modeling and QSAR.

It is also used in formulation optimization processes for dosage form designing and in biopharmaceutical analyses, such as pharmacokinetic modeling, pharmacodynamic modeling, in vitro-in vivo correlation analysis, etc.

Fuzzy logic and neurofuzzy logic

According to the routine rationale, proposition may be genuine or wrong. The theory behind the rationale lies either in or completely exterior the "true" set. When the speculation lies inside the "true" set, the participation work is indicated as "1" and when the speculation lies exterior the "true" set, the participation work is indicated as "0". The essential concept of fluffy rationale is promoted by LotfiZadeh within the 1960s. In contrast to the routine rationale, the fluffy rationale isn't restricted to be or 1. In any case, any nonstop esteem in-between these limits can be taken here. When 20°C temperature is taken as "comfortable", concurring to the ordinary rationale temperature of 19 or 21°C, which stay exterior this set, are "uncomfortable". But, concurring to fluffy

rationale, 17°C may get a enrollment of 0.4 within the "hot" set as well as 0.6 within the "cold" set. This rationale is exceptionally valuable in handle control. For the computerized circulations by the supply routes and venous, the mechanized framework based on fluffy rationale for sedate discharging has been surrounded and analyzed. Fluffy hemodynamic administration modules have as of now been utilized for the appraisal of the condition of patients to report the direction of the blood vessel as well as pneumatic weights. This will be utilized to screen the cardiac yield of patients.

The fluffy logic-based robotized framework offers a comparative speedier response and more stronghaemodynamic control. In expansion, the employments of supervisory-fuzzy rule-dependent versatile control framework is considered as a potential way for controlling the numerous medicate hemodynamic process. When the fluffy rationale framework is emphatically combined with a neural arrange, it is called as neurofuzzy rationale framework. Here, the capability of neural systems of learning from information and the capacity of fluffy rationale of communicating complex concepts naturally are combined appropriately. It has information mining capability. The neurofuzzy logic too presents neural arrange having 2 additional layers for the fuzzification of inputs as well as defuzzification of yields. In a investigate, the reenactment of probucol retention by means of the lipid definitions has been examined by implies of neurofuzzy networkings. Concurring to the result of the inquire about, the probucol releasing rate from the lipid formulations was found to be significantly lesser in comparison with that of the self-emulsifying formulations. The adaptive neurofuzzy network model together with in vitro-in vivo correlation tool demonstrated the competent predictive presentation and the prospective for the development of complex relationships as well as interpolates the pharmacokinetic constraints.

Principal component analysis (PCA)

PCA is another AI based demonstrate for diminishing the dataset-dimensionality by protecting as much 'variability' (i.e., factual data) as conceivable and at the same time, PCA demonstrating minimizes the misfortune of data. PCA displaying interprets into looking more current factors, which are straight capacities of those within the unique dataset by producing more up to date uncorrelated factors so that maximize the

fluctuation, successively.³⁰ Looking of such more up to date factors, the central components reduce the settling of an eigenvector or eigenvalue issue. PCA can be based on either the covariance framework or the relationship network and the most applications of PCA are descriptive in nature, instead of the inferential employments. Later a long time, PCA is well-known for utilizing as a 'hypothesis generating' AI device creating a valuable factual mechanics outline for displaying of natural frameworks without the necessity for solid a priori hypothetical suspicions, which makes PCA of fundamental noteworthiness for sedate disclosure inquire about by a systemic viewpoint overcoming as well contract reductionist approaches.

Support vector machine (SVM)

SVM approach is based on the idea of a hyper plane classifier or linearly separability. It is mostly dependent on Statistical Learning Theory (SLT). The aim of SVM is to discover a linear optimal hyper plane in order to that the margin of separation in-between the two classifications is maximized. SVM approach has recently been employed in many applications as it encompasses some potential benefits over various conventional machine learning methods. The important benefits of SVM approach are identified as:

- i) The solution of SVM approach is exclusive, optimal and global since the training of a SVM is done by solving a linearly confined quadratic problem.
- ii) Only two free parameters are required to be chosen. These are known as: the kernel parameter and the upper bound parameter.
- iii) SVM approach is capable of facilitating excellent generalization performance and good quality robustness.

Recent years, SVM approach has been employed for structure–activity relationship analysis and it proves its potential in drug discovery field. Burbidge et al. (2001) tested a benchmark test, where SVM approach was compared to several currently used machine learning techniques in the drug design field. The results of this research demonstrated that the SVM approach is significantly better as compared to these tested machine learning techniques currently used in drug designing, bar a manually capacity-controlled neural network, which takes considerably longer to train.

Hammeistern Weiner (HW)

HW modeling approach is one of the irrelevant to physiological AI models. This is more adaptable and way better able to adjust to information, which comes about in a prevalent fitting when compared to distinctive methods. HW show is actualized in case a cascade of two inactive nonlinear pieces and one direct square are utilized. As it were the straight square contains the energetic components. In a inquire about, Shokrollahi et al. (2018) assessed the utilize of a nonlinear Hammerstein-Wiener modeling within the improvement and control of a magneto-rheological liquid haptic gadget, which can be possibly utilized for automated bone biopsy.

The approval testing performed in this inquire about found that the HW modeling is able to anticipate the execution of the magneto-rheological liquid gadget with an exactness of 95% and the HW modeling is competent of dispensing with the hysteresis in a closed-loop control framework.

Advantages of AI technology

The potential advantages of AI technology are as follows:

i) **Error minimization:** AI assists to decrease the errors and increase the accuracy with more precision. Intelligent robots are made of resistant metal bodies and capable of tolerating the aggressive atmospheric space, therefore, they are sent to explore space.

ii) **Difficult exploration:** AI exhibits its usefulness in the mining sector. It is also used in the fuel exploration sector. AI systems are capable of investigating the ocean by defeating the errors caused by humans.

iii) **Daily application:** AI is very useful for our daily acts and deeds. For examples, GPS system is broadly used in long drives. Installation of AI in Androids helps to predict what an individual is going to type. It also helps in correction of spelling mistakes.

iv) **Digital assistants:** Now-a-days, the advanced organizations are using AI systems like 'avatar' (models of digital assistants) for the reduction of human needs. The 'avatar' can follow the right logical decisions as these are totally emotionless. Human emotions and moods disturb the efficiency of judgement and this problem can be overcome by the uses of machine intelligence.

v) **Repetitive tasks:** In general, human beings can perform single task at a time. In contrast to the human beings, machines are capable of performing multi-tasking jobs and can analyze more rapidly in comparison to the human beings. Various machine parameters, i.e., speed and time can be adjusted according to their requirements.

vi) **Medical uses:** In general, the physicians can assess the condition of patients and analyze the adverse effects and other health risks associated with the medication with the help of AI program. Trainee surgeons can gather knowledge by the applications of AI programs like various artificial surgery simulators (for examples, gastrointestinal simulation, heart simulation, brain simulation, etc.

vii) **No breaks:** Unlike human beings who have the capacity of working for 8 h/day with breaks, the machines are programmed in such a way that these are capable of performing the work in a continuous manner for long hours devoid of any kinds of confusions and boredom.

viii) **Increase technological growth rate:** AI technology is widely used in most of the advanced technological innovations worldwide. It is capable of producing different computational modelling programs and aims for the invention of the newer molecules. AI technology is also being used in the development of drug delivery formulations.

ix) **No risk:** In case of working at the risky zone like fire stations, there are huge chances of causing harm to the personnel engaged. For the machine learning programs, if some mishap happens then broken parts can be repairable.

x) **Acts as aids:** AI technology has played a different function by serving children as well as elders on a 24x7 basis. It can perform as teaching and learning sources for all.

xi) **Limitless functions:** Machines are not restricted to any boundaries. The emotionless machines can do everything more efficiently and, also produce more accurately than the human beings.

Disadvantages of AI technology

The important disadvantages of AI technology are as follows:

i) **Expensive:** The launch of AI causes huge money consumption. Complex designing of machine, maintenance and repairing are highly cost effective. For the designing of one AI machine, a long period of time is required by the R&D division. AI machine needs updating the software programmes, regularly. The reinstallations as well as recovery of the machine consume longer time and huge money.

ii) **No replicating humans:** Robots with the AI technology are associated with the power of thinking like human and being emotionless as these add some advantages to perform the given task more accurately without any judgement. If unfamiliar problems arise, robots cannot take the decision and provide false report.

iii) **No improvement with experience:** Human resource can be improved with experiences. In contrast, machines with AI technology cannot be enhanced with experience. They are unable to identify which individual is hard working and which one is nonworking.

iv) **No original creativity:** Machines with AI technology have neither sensitivity nor the emotional intelligence. Humans have the ability to hear, see, feel and think. They can use their creativity as well as thoughts. These features are not achievable by the uses of machines.

v) **Unemployment:** The widespread uses of AI technology in all the sectors may cause large scale unemployment. As because of the undesirable unemployment, human workers may lose their working habits and creativity.

AI in hospital pharmacy:

There are several applications of AI in hospital pharmacybased health care system in organizing dosage forms for individualized patients, selection of the suitable or available administration routes or treatment policies.

i) **Maintaining of medical records:** Upkeep of the restorative records of patients is complicated assignment. The collection, capacity normalizing, following of information are made simple by actualizing the AI framework. Google Profound Intellect wellbeing extend (created by Google) helps to unearth the restorative records in brief span of time. Subsequently, this extend could be a valuable one for way better and speedier wellbeing

care. The Field areas Eye healing center NHS is helped by this venture for advancement of eye treatment.

ii) **Treatment plan designing:**the planning of successful treatment plans is conceivable with the assistance of AI innovation. When any basic condition of quiet emerges and choice of reasonable treatment arrange gets to be troublesome, at that point the AI framework is fundamental to control the circumstance. All the past information and reports, clinical expertise, etc., are considered within the planning of treatment arrange as proposed by this technology. A program is propelled by IBM Watson to assist oncologists.

iii) **Assisting in repetitive tasks:** AI technology too helps in a few tedious assignments, such as looking at the X-ray imaging, radiology, Resound, ECG, etc., for the discovery and distinguishing proof of the infections or disarranges. Restorative Sifter (an calculation propelled by the IBM) is “cognitive assistant” having great expository and thinking capacity.

A restorative start-up is essential for the enhancement of persistent condition by combining profound learning with therapeutic information. A specialized computer program is accessible for each body portion and utilized in particular of disease conditions. Profound learning can be utilized for nearly all sorts imaging examinations, such as X-ray, CT filter, Reverberate, ECG, etc.

iv) **Health support and medication assistance:** Later a long time, the employments of AI innovation are recognized proficient in wellbeing back administrations conjointly, for the pharmaceutical assistances. Molly (a start-up outlined virtual nurture) gets a pleasant voice at the side a cheerful confront. Its point of it is for making a difference patients to direct the treatment of patients as well as supporting them with persistent condition between the doctor’s visits. Ai Remedy, is an app existing in Smartphone’s webcam, screens patients and helps them to control their conditions.

v) **AI helps to people in health care system:** It is capable of collecting and comparing the data from socialawareness algorithms. The vast information

recorded in healthcare system involves the medical history of the patients along with the treatment history profile from the birth, habits as well as life-styles of the patients.

AI approaches for drug discovery:The medicate revelation method starts from the accessible comes about accomplished from distinctive assets like highthroughput screening demonstrating, part screening demonstrating, computational demonstrating and existing information detailed. In medicate disclosure strategy, the auxiliary characterization of sedate particles can straightforwardly or by implication be analyzed by computer-assisted plan approaches and after this, natural blend of sedate atoms is done. The synthesized medicate atoms or collected medicate compounds are subjected to tall throughput screening in essential measure and after, that these are counter screened and assessed for their bioavailability in auxiliary tests along side fruitful structure action relationship (SAR) analysis.

The medicate disclosure trading among acceptance and finding forms. In this way, the conversely cycle of inductive–deductive handle eventually guides to achieve the optimized lead particles. The computerization of particular parcels of the inductive–deductive cycle diminishes the eccentricities and mistake; hence, progresses the adequacy of sedate disclosure method. Chemical and pharmaceutical producers look at and determine various licenses as well as genomic data-based logical science data by applying the profound learning program, e.g., “NVIDIA DGX-1”. Human creatures cannot work add up to accessible data for the progression of logical investigate. AI supercomputers are able to get and look at the data for identification the affiliation in-between the compounds to offer more up to date sedate molecules. The applications of AI in medicate revelation prepare concerns the utilize of chemical space. In truth, the chemical space offers the stage for the recognizable proof of modern atoms since it is achievable to computationally order the required molecules. In expansion, the machine learning and related prescient instruments also help for the distinguishing pieces of proof of target-specific compelling atoms. The method of selecting a effective unused sedate molecule from huge amount of pharmacological active chemical substances is the hardest portion of the total wonder. Kind AI is utilized for the reason of preparing less particles with much more surety approximately their action. In this respect, de novo

plan require the understanding of natural chemistry for the amalgamation of in silico particles and the virtual screening displaying that perform as the substitutions for numerous biochemical as well as natural testing to degree the proficiency as well as harmfulness profiles. The point of de novo plan within the sedate revelation is the innovation of more current dynamic atoms without the employments of reference particles.

At last, the dynamic learning calculations allow the disclosure of unused atoms with the potential activities against the target-setting of illnesses or clutters. A few in silico strategies for the choice of profiles like ligand-based plan approaches or atomic structure-based plan approaches may be utilized beside the open data on the small atom modulator tests or the highlights of auxiliary science. Insilico atoms is getting the following era AI. There are different recommendations and program arrangements open for it. This plan isn't valuable in sedate disclosure; but, it is associated to the era of components having trouble in blend.

Although recursive neural networks are applied for de novo design, it is mainly introduced in the field of natural language processing. The sequential information is taken as input by recursive neural networks. As the molecular structures are encoded as a series of letters by SMILES strings, recursive neural networks are employed for generating the chemical structures of molecules. The neural networks are taught the grammar of SMILES strings by mean of training recursive neural networks with a wider setting of chemical compounds from the existing/available chemical compounds from existing compound collections (e.g., ChEMBL).

The recursive neural networks have the capability for the processing of a high fraction of authentic SMILES strings. This approach is also applied for the creation of newer peptide structures. The reinforcement learning is also used in favour of the generated chemical molecule towards the desired characteristics. Another useful strategy is transfer learning used for generation of newer chemical structures processing a proper biological characteristics.

This strategy possesses two steps.

The step1 consists of training of the network for learning SMILES grammar.

The step 2 consists of continued training with compounds possessing proper desired property. Such few extra epochs of training are enough in

favour of the generation of newer compounds as into a chemical space possessed by the active molecules. Depending upon these approaches, in a work, synthesis of five molecules is done with the conformation of the design activity for four molecules against the nuclear hormone receptors. There is a fascinating method in the sphere of AI named 'Variational Autoencoder' having 2 neural networks:

- (i) Encoder networks and
- (ii) Decoder networks. The translation of chemical structures is illustrated by SMILES.

This represents into a real-value continuous vector as the latent space and translation of vectors from which the latent space into the chemical structures are performed by encoder networks as well as decoder networks, respectively. The latent extent description is required by the authors for the training of a model which is dependent on synthetic accessibility score (SAS) and QED drug-likeness score.

It is then possible to acquire a passage of molecules with upgraded target properties. In a published report, the comparison of 'Variational Autoencoder' with an 'Adversarial Autoencoder' was shown according to their performance. The 'Adversarial Autoencoder' has greater capability for producing appreciably more authentic molecular structures in comparison with that by the 'Variational Autoencoder' during their generation mode. Generative adversarial networks (GANs) are capable for the designing of drug molecules. The technology can prepare photo-realistic pictures from the text representation. In a work, Kadurin et al. (2017) employed GAN for suggesting compounds having anticancer characteristics.

Imagination or creations of new data can also be done by this technology based on the real data. Next generation AI is not dependent on the learning from large data sets. The new AI technology is capable to handle all the problems that are difficult to solve previously. The scientists and researchers are assisted by this new technology in the identification and selection of promising chemical agents on the basis of their efficacy, safety and selection of patients to the clinical trials. Therefore, AI is helpful in drug delivery because of its capability of prioritising the molecules according to the simplicity of syntheses or development of useful tools, which have been

proved effectual for the most favourable synthetic technique.

AI approaches for development of drug delivery systems

Generally, the designing of drug delivery systems is related to some disadvantages like prediction of the relationship amongst the formulation factors and responses. This is also related to the therapeutic outcomes and the unpredicted occurrences. In the designing of different kinds of intelligent drug releasing systems, the on-demand dose adjustment or the rates of drug releasing, targeted releasing and drug stability are the important factors. Concerning the self-monitoring systems for releasing of drugs, the suitable algorithms are useful for controlling the quantity as well as the period of drug releasing. Therefore, AI approaches are useful for the prediction of the drug dosing efficacy and drug delivery potential of the drug delivery dosage forms.

Solid dispersions: The ANN modeling combined with experimental design has been employed to develop solid dispersions of carbamazepine using poloxamer 188 and Soluplus. The aim of the preparation of carbamazepine solid dispersions was to improve the carbamazepine solubility and dissolution rate. These carbamazepine-Soluplus-poloxamer 188 solid dispersions were synthesized via the solvent casting technique.

In a research, a modeling of ANN (a feed-forward back propagation) with the logistic sigmoid activation function has already been employed for the analyses of linking amongst different variables as well as dissolution properties for the optimization of dissolution rate of drug. In this work, to prepare the solid dispersions of drug, poly (vinylpyrrolidone)/polyethylene glycol mixtures were used as carriers. The applied ANN assisted modeling established an appropriate prediction for the solid dispersion preparations of drugs with desired dissolution properties with along-standing physical stability.

Emulsions and microemulsions:

ANNs have also been utilized for the formulation development of stable emulsions (oil/water). The optimization of the fatty alcohol concentration to formulate emulsions (oil/water) was analyzed in this work. The independent variables (factors) analyzed in this work were

concentrations of lauryl alcohol and time. The dependable variables (responses) were droplet size, zeta potential, viscosity and conductance. On the basis of validation testing, ANN-predicted values were found in excellent correlation with the data obtained from the experiment.⁵⁹ ANNs have also been applied in the formulation designing of microemulsions, where the prediction of precision based on the microemulsion nature from the formula was easily analyzed.⁶⁰ By means of the mixture of genetic algorithms and evolutionary ANNs, interior structural features and the microemulsion nature have also been forecasted with the high level of precision. In another work, an ANN modeling has been employed to forecast the formulation of stable microemulsions loaded with antitubercular drugs like rifampicin and isoniazid for oral administrations. Data obtained from the constructed pseudo-ternary phase triangle-diagrams presenting the oil components and the surfactant mixture were used for the testing as well as validation of the ANN modeling.

Tablets:

In the designing of matrix tablets, static and dynamic ANNs have been applied for the dissolution profile modeling of different matrix tablets. In this work, Monte Carlo simulations and the genetic algorithms optimizer tool were applied for these modelings based on ANN algorithm. The researcher used the Elman dynamic neural networks and decision trees, which appropriately predicted the dissolution properties of hydrophilic as well as lipid-based matrix tablets exhibiting controlled drug releasing pattern. As compared to the majority of commonly employed multilayer perceptron and static networks, the Elman neural networks-based modeling demonstrated the efficient modeling of drug releasing patterns by various formula of hydrophilic as well as lipid-based matrix tablets.

In a research, matrix tablets for sustained release of an antidiabetic drug, metformin HCl, was developed by means of multilayer perceptron with feed forward back propagation technique. The in vitro metformin HCl releasing pattern by the matrix tablets was optimized to develop the optimized formulations. The independent variables (factors) and dependable variables (responses) were analyzed for network training. In addition, the leave-one-out technique was employed for the model validation process by means of several trials.

In another work, ANNs was applied for the formulation optimization of nimodipine matrix tablets for controlled releasing application. A combination of ANN-based modeling and statistical optimization process has been employed for the formulation designing of glipizide releasing osmotic pump tablets. In addition to the dissolution testing of these glipizide releasing osmotic pump tablets, the different formulation variables and process variables were optimized and analyzed by means of ANNs.

A mixture of response surface methodology (RSM) and ANN-based modeling has been applied for the formulation optimization of osmotic tablets containing isradipine. The disparity amongst the predicted dissolution results and observed dissolution results for the optimized is radipine osmotic tablets was found to be within the experimentally caused error limits.

In addition, the difference as well as similarity factors did not have any difference among the predicted dissolution results and observed dissolution results, demonstrating the appropriateness of ANN-based modeling to achieve the desired dissolution pattern for the formulation development of the controlled is radipine releasing osmotic tablets.

Multiparticulates (beads, microparticles and nanoparticles):

By employing CAD/ Chem software assisted modeling, multi particulate beads of verapamil was developed. In this work, the influences of various formulation variables as well as process variables on the in vitro verapamil releasing by the beads were analyzed. The in vitro verapamil releasing data for the optimized beads were found to be in the line of good agreement in comparison with that of the predicted results obtained by the ANN modeling.

In a work, ANN modeling was applied to assess the influence of process variables on the papain (enzyme) entrapment within alginate-based beads for the improvement of stability as well as sitespecific release. The combination of ANN and RSM was applied to optimize alginate-based floating microspheres of aspirin, where the quantities of excipient materials, drug releasing and buoyant rate of microspheres were analyzed. ANN model was more precisely predicted in vitro aspirin releasing pattern in comparison with that of RSM. In a work, both the ANN model and factorial model as multivariate methods were used to develop the polymeric microspheres of

verapamil HCl. The mutual impacts of external phase pH, initial loading of verapamil HCl and concentration of polymer used on various properties of microspheres was analyzed.

The results of the study clearly demonstrated that ANN model showed the better fitting abilities with comparatively less biased and more accurate predictability in comparison to the factorial model. RSM by full factorial design was employed for the formulation development of tamarind seed polysaccharide-alginate composite beads loaded with diclofenac sodium, where the impact of sodium alginate to tamarind seed polysaccharide ratio and cross-linker (calcium chloride) concentration as independent formulation variables on the drug encapsulation efficiency and drug release were statistically analyzed. Suitable polynomial equation involving independent formulation variables (factors) and their interactions was analyzed based on the estimation of several statistical parameters, such as correlation coefficient (R^2), predicted correlation coefficient (predicted R^2), adjusted correlation coefficient (adjusted R^2) and predicted residual sum of squares (PRESS), provided by the Design-Expert® Software.

In this research, two quadratic models were selected as suitable statistical modeling for optimization for drug encapsulation efficiency and drug release as responses, as because both the responses analyzed had the negligible PRESS values. PRESS is well-known statistical parameter for the measure of model fit to the data points and the smaller PRESS statistic indicates the better model fit to the data points. The predicted values obtained from the full factorial designs were coincided well with the observed responses.

In a research, central composite design and RSM were employed for the formulation optimization of alginate– methylcellulose mucoadhesive microcapsules loaded with gliclazide, where the impact of sodium alginate to methylcellulose ratio and cross-linker (calcium chloride) concentration as independent formulation variables on the drug encapsulation efficiency and drug release were statistically analyzed.

The statistical modeling was evaluated by one-way ANOVA ($p < 0.05$) for all the responses (namely density, ibuprofen entrapment and ibuprofen release). The in vitro drug release data were evaluated kinetically using various mathematical models. The R^2 and root mean squared error (RMSE) values of these mathematical models were computed using

KinetDS 3.0 Rev. 2010 software for accuracy as well as prediction capability of these mathematical models.

When the respective R² were compared, the Korsmeyer–Peppas model was found as best-fit kinetic model. However, it was also observed to be closest to zero order model, Weibull model and Baker–Lonsdale model. Finally, the best fitting of the Korsmeyer–Peppas model was verified by comparing RMSE values for each tested models, where the minimum RMSE values (0.12–0.68) was found. In a work of development of albumin-loaded chitosan nanoparticles, ANN modeling was employed for the analyses of the impacts of various independent variables (factors) on the dependable variables (responses) like albumin loading efficiency and cytotoxicity profile. A 3 layer feed forward back propagation-based ANN modeling was studied for the development of nanoparticles of tri-block poly(lactide)–poly(ethylene glycol)– poly(lactide) copolymer. In this work, on the basis of correlation coefficient (R²) and mean squared error (MSE) values, the best analytical model for prediction was chosen for training, test as well as data validation analysis. Amongst all the investigated variables, the concentration of polymer in the copolymer-based nanoparticle formulation was revealed as the most impacted factor. On the basis of central composite design (spherical), the formulation development of polymer-lipid hybrid nanoparticles of verapamil HCl was carried out, where the impacts of various formulation factors were analyzed. The multi-objective optimization of polymer-lipid hybrid nanoparticles of verapamil HCl was carried out employing the validated ANNs and continuous genetic algorithms and the analyses results indicated the better analytical capability of ANN model.

AI approaches in polypharmacology

Now a day, ‘one-disease-multiple-targets’ concept governs over the ‘one-disease-one-targets’ concept for the advanced realization of pathological process in various disorders at their molecular basis. The phenomenon of ‘one-disease-multiple-targets’ is known as polypharmacology.

There are numerous and useful databases, for examples, PubChem, KEGG, ChEMBL, ZINC, STITCH, Ligand Expo, PDB, Drug bank, Supertarget, Binding DB, etc, which are accessible for the accomplishment of a variety of important and useful information related to the structure of crystals, chemical features, biological properties,

molecular pathways, binding affinities, diseaseconcern, drug targets, etc. AI also helps to discover the databases to sketch polypharmacological molecules/agents.

II. CONCLUSION

During past few years, a considerable amount of increasing interest towards the uses of AI technology has been identified for analyzing as well as interpreting some important fields of pharmacy like drug discovery, dosage form designing, polypharmacology, hospital pharmacy, etc. as the AI technological approaches believe like human beings imagining knowledge, cracking problems and decision making.

The uses of automated workflows and databases for the effective analyses employing AI approaches have been proved useful. As a result of the uses of AI approaches, the designing of the new hypotheses, strategies, prediction and analyses of various associated factors can easily be done with the facility of less time consumption and inexpensiveness.

ABBREVIATIONS

- AI:** Artificial intelligence;
AGI: Artificial general intelligence.
ANI: Artificial narrow intelligence.
ANN: Artificial neural network.
DNN: Deep neural network.
GAN: Generative adversarial network.
QSAR: Quantitative structure-activity relationship.
QSPR: Quantitative structure-property relationship.
RNN: recurrent neural network.
SAS: Synthetic accessibility score.

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