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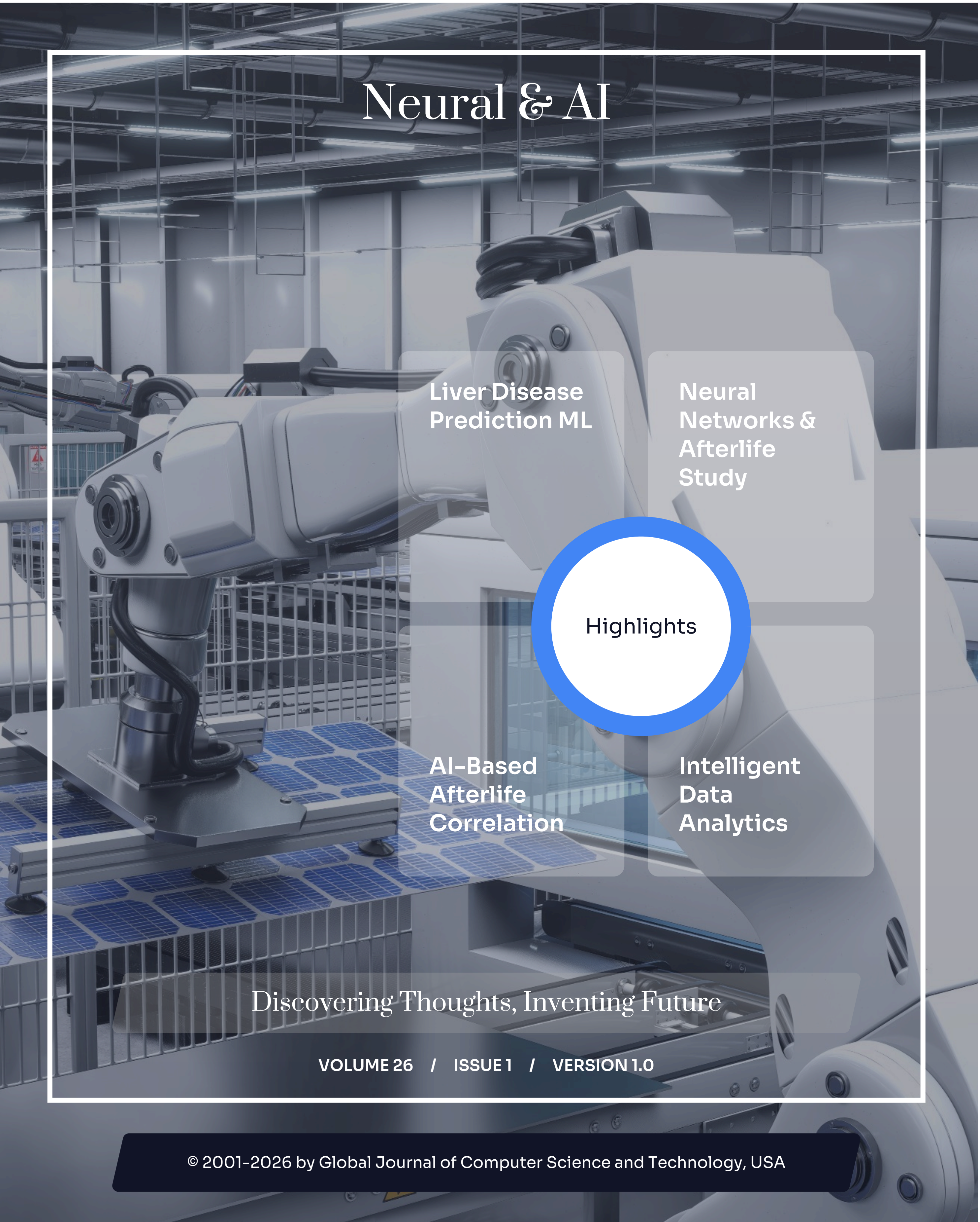

# Neural & AI

Liver Disease Prediction ML

Neural Networks & Afterlife Study

Highlights

AI-Based Afterlife Correlation

Intelligent Data Analytics

Discovering Thoughts, Inventing Future

VOLUME 26 / ISSUE 1 / VERSION 1.0

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Neural & Artificial Intelligence

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# Neural Networks and Rules-based Systems used to find Rational and Scientific Correlations between being here and now with Afterlife Conditions

By Francesco Pia

*Abstract-* What you will read in the next pages is an anthology-worthy element and should be taken seriously. In this work, we attempt to describe a place that is unknown and therefore difficult to define, in the sense of arriving in an unknown place, which therefore will not be easy to describe. In the path that takes us from non-existence to being and becoming. Placed in this location, it becomes interesting that different things or people coexist that have not yet been presented in the era in which we connect and go to browse. A very important aspect is the determination of the window in which one says he had a dream where he saw a car that does not yet exist today but perhaps will exist in the future, or a deceased person or one who will exist in the future; So, once the time window is set, which isn't easy, and determining it is an important aspect in which brainwaves will then be selected.

*Keywords:* *alien, spaceship, domus de janal.*

*GJCST-D Classification:* *LCC Code: QA76.87*

NEURALNETWORKSANDRULESBASEDSYSTEMSUSEDTOFINDRATIONALANDSCIENTIFICCORRELATIONSBETWEENBEINGHEREANDNOWWITHAFTERLIFECONDITIONS

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Francesco Pia

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We would therefore try to obtain feedback from the Afterlife in order to reproduce the brain waves seen in the dream phase thanks to a helmet connected to proactive and not just generative Artificial Intelligence.

*Keywords: alien, spaceship, domus de janal.*

## I. Introduction

In the flow of events from the origin to today up to the place where everyone, and everything, would go as in the problem of the two twins: no one has ever returned from where they came out and the two discuss what the "world" outside them known could be like. We have to think about the second-order state of consciousness (conscious of being so) and then we have a higher, global consciousness of the path and therefore the choice that we (with our free will) operate; our presence here and now is the constituent of a complex, harmonized design, shaped by the Creator. So, time doesn't exist, but position does, and therefore. Everyone (and everything) would end up in the same position. The idea would be to study and engineer a system that can be tuned to a helmet that reproduces the brainwaves learned during the training of the intelligent system. With this system, we're trying to select EEG spots from people who see the dead in their dreams or think of them as being dead: those who are in the afterlife or have not yet appeared. So we need to select these brain waves, and since a wave can be the result of many waves, that is, we're talking about a tuner. Upon reentry, the signals are composed of certain electromagnetic waves that, when transmitted into the helmet, will allow us to reproduce and see the place of the dead, and perhaps interact as if the dream were being relived. Second-order consciousness places paramount importance on the individual; many, becoming aware of a fact, would feel uncomfortable about infringing on others because we'd all end up in the same place anyway. Who's to say the guy you wronged can't retaliate and have the capacity to do so?

## II. Methods and Tools

In the journey, or flow of existence, the passing completes the person who is aware of it, a consciousness on the journey, so we can call it: *third-order* consciousness; this will be highlighted by the feedback of signals produced by a computer system and transmitted to the helmet and then to the brain, so that it can relive more fully, close to the (experiential) window of the signal correlated with the one it itself generated.

A first investigation method would be to select some people with strong dreaming abilities and who can be defined as "lucid dreamers", monitor them with an electroencephalogram and measure their brain waves for 24 hours and then verify, if applicable, whether they have had dreams or thoughts related to the deceased or the afterlife and record the signals in the selected time window; once this is done, neural networks are used, even if they are time series, to see if when we think while awake, ordinary people have the same waveforms.

However, it must be said that the intelligent system trained to recognize EEG waves will also include those while awake; because one can imagine, or think, of a parent, for example, or of a deceased loved one (it's

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premature to think of who will come next)... Napoleon, Julius Caesar, for example: in that moment one thinks about it intensely: what or what waves does the brain manifest? Certain particular characteristics can be found, the one just described is a first method.

We would like to connect to the possible location called Afterlife with a feedback that goes back to the here and now by connecting the helmet that will give its own signals that can be selected for the event considered by the user.

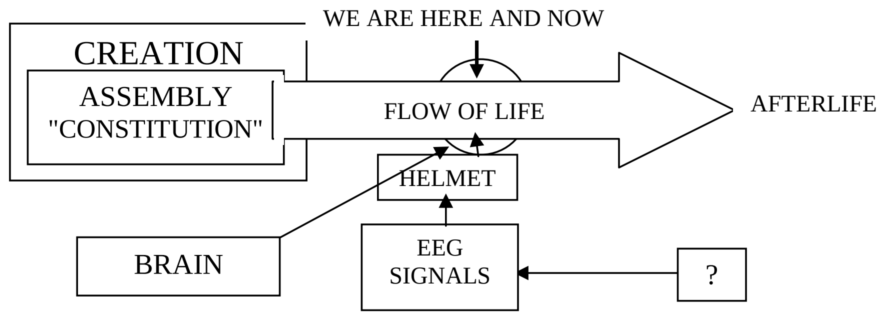


*Fig. 1:* This figure represents the timeline from the origin, birth, the path of "life", where we are here and now, until death and the eventual transfer of the spirit to the Afterlife

Another very important aspect is represented in the following figure *Fig. [2]* present in the parallel universes in *[11]*, being there the path that reproduced gratifying the idea that it exists, let's say teleportation *[7]*; but it is also important instead the existence of an indefinite limit of all situations or possible choices: everything flows into a circle that surrounds everything as a limit of all things and all paths, therefore this circle represents the window towards the environment that we call Afterlife, otherwise it is necessary to delve deeper or/and change hypothesis.

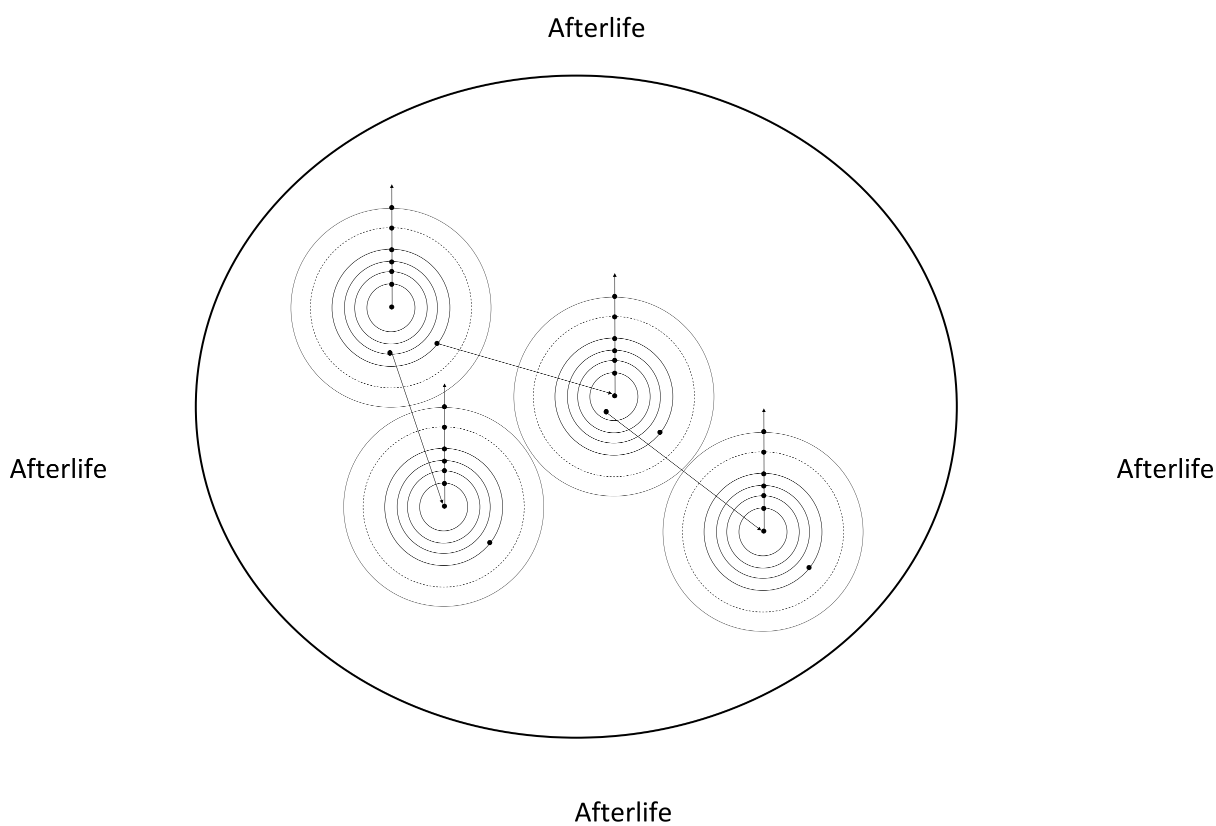


*Fig. 2:* In this figure it is represented more than one line of events that arise from "point" configurations of any circumferences and circle conjunction

The paradigm we want to use is always the same: a very weak hypothesis that allows us to be more imaginative. The weak hypothesis is that we can tune audio-video to the place where all the dead are (perhaps even those yet to be born or become) in the becoming (flow) of life from the beginning to the end and the presence: I am here, I was. no one knows where, but it is a place where everyone is dead, or has yet to be born, time not existing: the condition is persistence in an environment where everyone is present, and therefore like, for example, a golf ball that from the beginning-the construction of the materials, the assembly, the formation of the ball, the positioning, the swing with the club, the arrival at the hole-is taken from there, then, since time does not exist, it will be destroyed like everything else; nothing persists and nothing continues to be assembled.

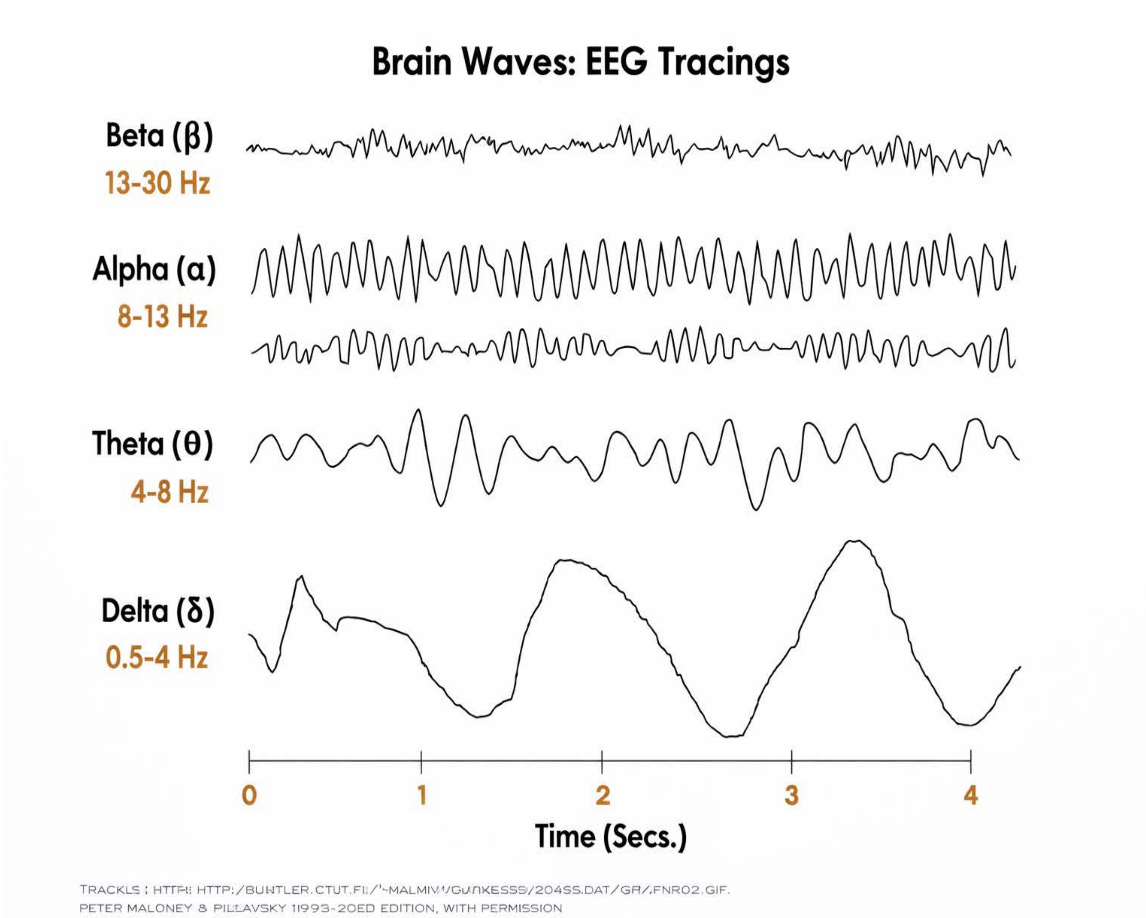


*Fig. 3:* This Figure Shows the Characteristic Curves of an EEG

The system, with the helmet and the transmitted signals, and with good correlation (in this work, correlation means the ability to narrow the window within which the brainwaves are then selected), can record all brain activity, creating slots, especially when the individual customizes the use of the helmet, for example during an inspection, and would like to relive that situation at a later time; this system should help. Indeed, by reproducing the recorded waves completely this time (thanks to Shanon's theorem and complete correlation), and therefore also the time windows are well-defined, the experience is reproduced, so it can be helpful when thinking about a specific or nuanced situation; this fact needs to be verified with experiments.

This would be a significant innovation in the field of on-site inspections of human activities-industrial, civil, medical, scientific, military, and psychophysical. The applications are countless, and this must be taken into account when launching a startup (a pilot project to engineer the ideas described here). Using generative AI, the system's response, or its correlation within the time window, could be improved by placing flags (that draw attention, such as a milestone, an object, a situation). These flags, during training, likely make them more perceptible, improving the brain's compliance with the system. The brain then responds better by facilitating brainwaves to relive the recorded situation and correlate it with the recorded "slot" trained to memorize and highlight certain aspects.

*a) An Example*

*An illustrative example is presented below based on a documented dream experience*, and we'll tell you about it. A few days ago, we saw a TV program about the Domus De Jana, ancient Nuragic-sized structures found in great numbers only in Sardinia.

The dream in question is classified as level one, very bright, lasting about fifteen minutes and ending at a verifiable time. Nuragic structures are presumably difficult for humans to construct; While I was having lunch with hunter friends, and it was a lovely time, with roast meat, red wine, and smiles, in the woods on one side of a promontory, on the opposite side I saw a spaceship crash and explode on the opposite side from where I was. I couldn't dial the fire department. The flames were high, devices like tablets and cell phones weren't working. At that point, I asked a doctor friend to leave me her cell phone, and it also had a special system for entering numbers, but she managed to call the emergency number and the switchboard answered, which put me through to the fire department. That's how it works in real life. While the fire department was being passed on to me, I approached to help the alien, and what could I see? First of all, a huge excavation at least ten meters deep, and other friends from my town who had nothing to do with it, with their lunch, and those who were having lunch weren't worried about anything. A huge excavation that two bulldozers couldn't complete in three days. Inside, neatly arranged, were pieces of the spaceship and a mix of technology and feudalism, a lot of technology; neatly arranged, to be buried later: the conclusion is that the dream, presumably, the Domus de Jana have an alien connotation. This is, however, a dream, emphasizing that the Domus de Jana, and the aliens in fact, may not exist in reality. It's also true that the project manager was a friend of mine, with a poor academic record but industrious in construction (he renovated his house... and what a job). Where did the alien go?

## III. Conclusion

In our life journey, we are, those who are, natural lucid dreamers up to the fourth level, very clear, premonitory, we find lost objects: these things happen. However, writing this work would have been "*impossible*" if we had chosen differently along our life journey: a yes to a job offer where we said no, a different girlfriend, a yes to a different financial situation, etc.; something different from the path we experienced would have been generated. We attach great importance to this work, in the sense that we should be more aware of the physiology that has formed. Therefore, with the third-order state of consciousness, we have a very important concept that should give us pause. Let's assume, hypothetically, that everything is working correctly; therefore, a person who reviews their dreamed or lived experiences works: loved ones, objects, people they have never met because they were not yet born or previously died; Let's assume this happens and the person becomes less subservient and eager to stay connected, at this point we face a question: is it truly an

Afterlife or is it simply a bluff, an unknown quantity? This isn't easy to know yet. In the existence of a possible Creator, which we believe exists, everything makes sense if we arrive somewhere-the famous Afterlife-to flow into a "happy" island. a destination point, and thinking about the beyond is not the case, for now.

A positive aspect, we believe it almost always is, is the lifestyle changes that can develop from a consciousness of the path (of the third order). After all, we would probably end up in the same place, not in the flesh but in spirit, all there; perhaps it's time to behave more lovingly?

After all, he who sows the wind (love/hate) reaps the whirlwind (love/hate) even in the afterlife?

## Acknowledgment

An extraordinary thank you to all those who take care of people with physical and mental disabilities

# Neural Networks and Rules-based Systems used to find Rational and Scientific Correlations between being here and now with Afterlife Conditions

Francesco Pia

*Abstract-* Quello che leggerete nelle prossime pagine è davvero un elemento degno di un'antologia, nel senso che va preso sul serio; è infatti il luogo che cercheremo di descrivere in quest'opera, nel senso di approdare in un luogo sconosciuto, che quindi non sarà facile da descrivere.Nel percorso che ci porta dal non esistere all'essere e al divenire. Collocati in questa location, diventa interessante il fatto che coesistano differenti cose o persone che ancora non sono state presentate nell'epoca in cui noi ci colleghiamo e andiamo a curiosare. Un aspetto molto importante è quello della determinazione della finestra in cui uno dice di aver fatto un sogno dove si è vista una macchina che oggi ancora non esiste ma forse esisterà in futuro, oppure una persona defunta oppure che esisterà nel futuro; quindi, fissata la finestra temporale, fatto non semplice, e determinarla è un aspetto importante nel quale poi si selezioneranno le onde celebrali. Tale selezione è facile e preciso quando si è svegli e si pensa una cosa e la finestra temporale è ben chiara, quindi basta una piccola interazione con la persona cosa differente è quando si sogna. Esiste il teorema di Shannon, usato in Elettrotecnica e Telecomunicazioni, che aiuta a selezionare "correlare" i segnali. Del perché si sia pensato a questo teorema, cruciale per campionare efficacemente dei segali e poterlo ricostruire completamente, a pranzo con la famiglia è uno di quei misteri che ci portano a chiederci: abbiamo un collega?

Dobbiamo perfezionare quindi lo start e lo stop di registrazione durante il sogno stringendo dove di interesse, utile per scoprire che pensiamo e che il nostro cervello ci propone cose che davamo per disperse nella nostra cultura storica e invece improvvisamente. Emerge quello che serve.

Cercheremmo quindi di ottenere un feedback dall'Afterlife in modo da riproporre le onde cerebrali viste in fase onirica grazie ed un casco collegato con l'Intelligenza Artificiale propositiva e non solo generativa.

*Keywords: alien, spaceship, domus de janal.*

## I. Introduction

Nel fluire degli eventi dall'origine ad oggi fino al luogo dove tutti, e tutto, andremmo come nel problema dei due gemelli: nessuno è mai rientrato da dove sono usciti e i due discutono come potrebbe essere il "*mondo*" fuori da loro conosciuto. Abbiamo da pensare allo stato di coscienza del secondo ordine (cosciente di esserlo) e poi abbiamo una coscienza superiore, globale, del percorso e quindi la scelta che noi (con il nostro libero arbitrio) operiamo; la nostra presenza *qui e ora* è il costituente di un disegno complesso, armonizzato, plasmato dal creatore. Quindi, non esiste il tempo ma la posizione e quindi... tutti (e tutto) finiremmo nella stessa posizione. L'idea sarebbe quella di studiare, ingegnerizzare, un sistema sintonizzabile con un casco che riproducendo le onde cerebrali che "sono" quelle apprese durante l'addestramento del sistema intelligente con il quale noi stiamo cercando di selezionare spot di EEG di persone che vedono nei sogni o pensano i morti: che sono nell'aldilà o non ancora apparsi. Quindi dobbiamo selezionare queste onde cerebrali e siccome un'onda può essere frutto di molte onde, ovvero, si parla di un sintonizzatore; al rientro i segnali sono composti da certe onde elettromagnetiche che veicolate nel casco permetterà di riprodurre e *vedere* il luogo dei morti e forse di interagire come se il sogno fosse rivissuto. La coscienza del secondo ordine da un'importanza apicale al singolo, molti prendendo consapevolezza di un fatto e così si troverebbero a disagio nel fare una prevaricazione perché tanto finiremmo tutti nello stesso posto e chi lo dice che il tipo a cui hai fatto un torto non si possa rivalere e ne abbia le capacità?

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## II. Methods and Tools

Nel percorso, o fluire dell'esistenza il trapasso completa la persona che è consapevole di ciò, una coscienza sul percorso, quindi possiamo chiamarla: coscienza del terzo ordine; questo sarà messo in luce con il feedback dei segnali che verranno prodotti da un sistema informatico e trasmessi al casco e quindi al cervello, cosicché possa rivivere più completamente "*pienamente*", vicino alla finestra (esperienziale) del segnale correlabile da quello che ha generato lui stesso.

Un primo metodo di indagine sarebbe selezionare alcuni persone con spiccate capacità oniriche e che possono essere definiti "*sognatori lucidi*", monitorarli con un elettroencefalogramma e misurare per 24h le onde cerebrali e quindi verificare, se capita, se hanno avuto sogni o pensieri legati ai defunti o all'aldilà, e registrare i segnali nella finestra temporale giustappunto selezionata; fatto questo, si utilizzano le reti neurali, anche se sono serie temporali, per vedere se quando pensiamo da svegli, le persone comuni, hanno le stesse forme d'onda. Però c'è da dire che nel sistema intelligente che viene addestrato per riconoscere le onde dell'EEG ci saranno anche quelle da sveglio; perché si può immaginare, o pensare, ad un genitore, per esempio ad un genitore, o ad un caro defunto (a chi verrà è ora prematuro)... a Napoleone, Giulio Cesare per esempio: nel momento lo si pensa intensamente: il cervello cosa o che onde manifesta? Possono essere rinvenute certe caratteristiche particolari, questo appena descritto è un primo metodo.

Noi vorremmo collegarci all'eventuale location chiamata Afterlife con un feedback che torna indietro al qui e ora collegando il casco che darà dei segnali propri potranno essere selezionati per l'evento considerato dall'utente

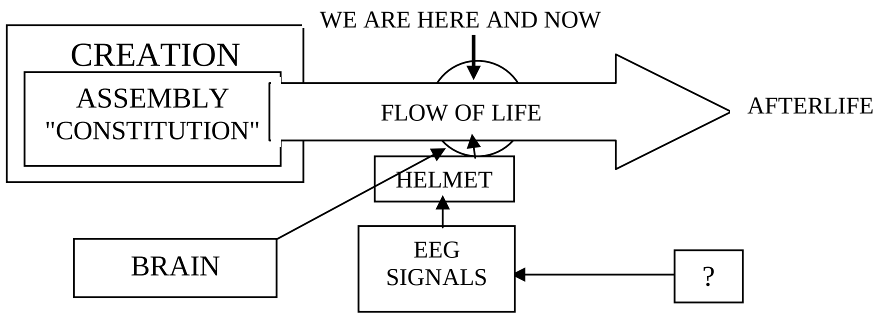


*Fig. 1:* In questa figura è rappresentato lo schema della linea temporale dall'origine, nascita, il percorso "della vita", dove stiamo qui e ora, la morte e l'eventuale trasferimento dello spirito al Afterlife

Un'altro aspetto molto importante è rappresentato nella seguente figura *Fig. [4]* presente negli universi paralleli in *[11]*, essendoci il percorso che riprodotte gratificano l'idea che esista, diciamo il teletrasporto *[7]*; ma è anche importante invece l'esistenza di un limite indefinito di tutte le situazioni o eventuali possibili scelte: tutto confluisce in un cerchio che circonda tutto come limite di tutte le cose e di tutti i percorsi, quindi questo cerchio rappresenta la finestra verso l'ambiente che noi chiamiamo *Afterlife*, diversamente è necessario approfondire o/e cambiare ipotesi.

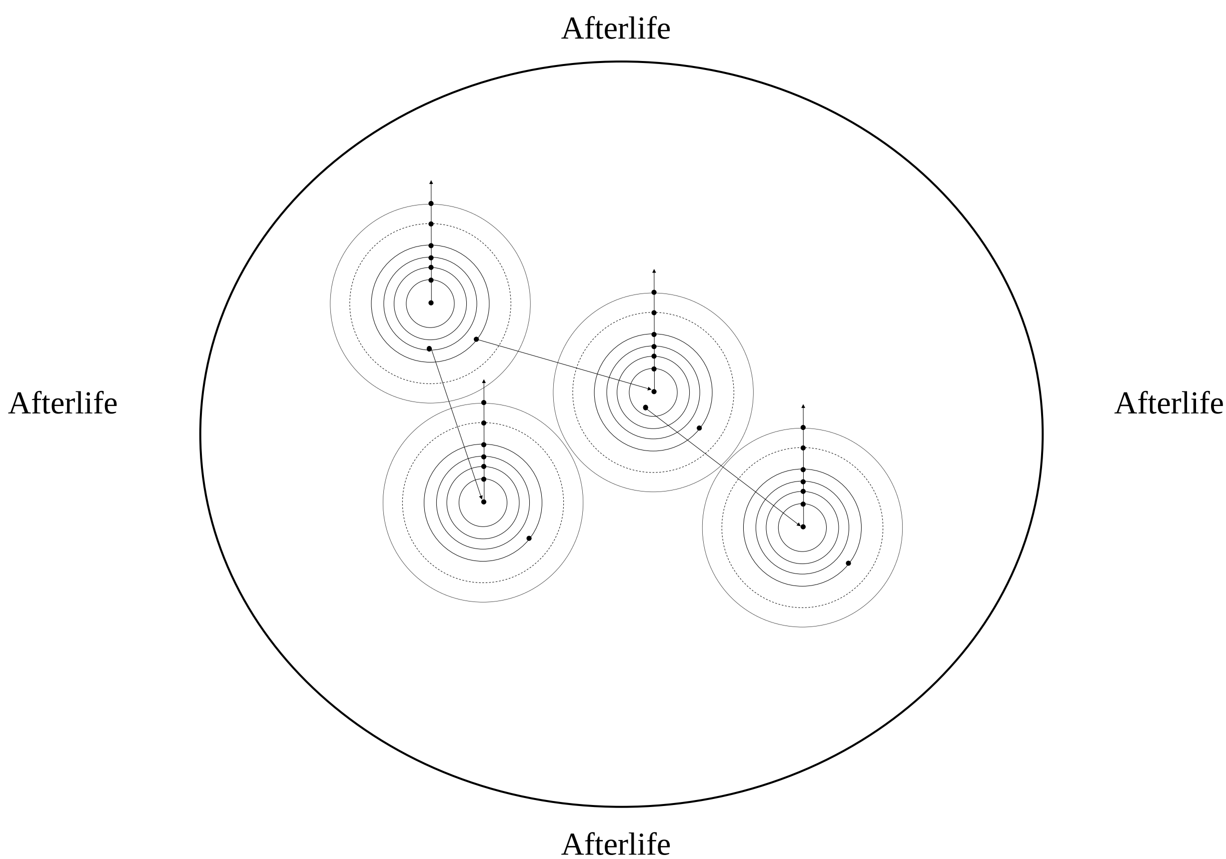


*Fig. 2:* In this figure it is represented more than one line of events that arise from "point" configurations of any circumferences and circle conjunction

Il paradigma che si vuole utilizzare è sempre il solito: un'ipotesi molto debole che ci permette di avere una maggiore immaginazione. L'ipotesi debole è che si possa sintonizzare audio-video il luogo dove sono tutti i morti (magari anche quelli che devono ancora nascere o divenire) nel divenire (fluire) della vita dall'origine fino alla fine e la presenza: *io sono qui*, ero... non si sa dove, è però un luogo dove sono tutti morti, o devono ancora nascere, non esistendo il tempo: la condizione è di persistenza in un ambiente dove si trovano tutti e quindi come per esempio una pallina da golf che dalle origini: la costruzione dei materiali, l'assemblamento, la formazione della pallina, il posizionamento, lo colpo con la mazza, l'arrivo fino in buca, da li viene presa poi siccome il tempo non esiste si distruggerà come tutto, non persiste niente e nulla continua ad essere assemblato.

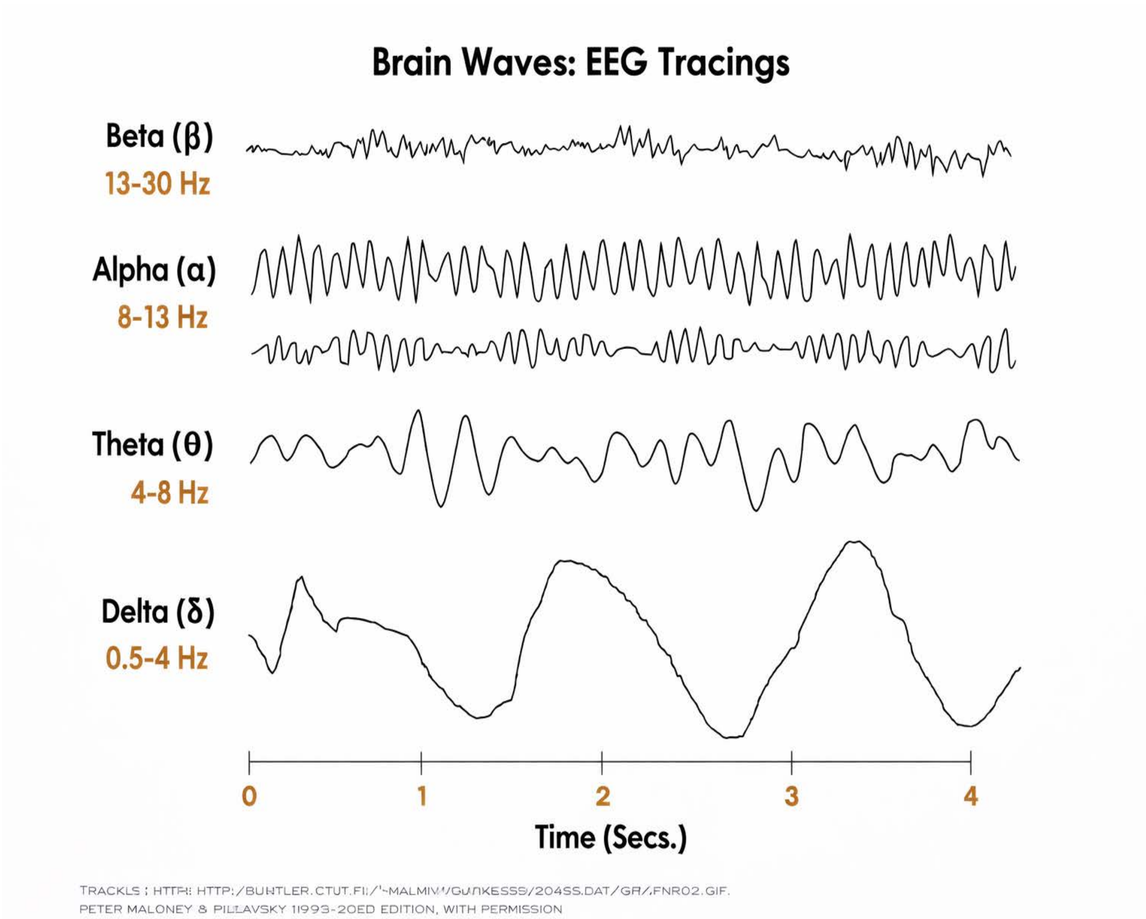


*Fig. 3:* In questa figura sono rappresentate le curve caratteristiche di un EEG

Il sistema con il casco e i segnali trasmessi e con una buona correlazione (in questo lavoro per correlazione si intende la capacità di stringere la finestra in cui poi verranno selezionate le onde cerebrali), si può registrare tutta l'attività cerebrale, facendo degli slot, sopratutto quando l'individuo personalizza l'uso del casco per esempio durante lo svolgimento di un sopraluogo, e vorrebbe rivivere quella situazione in un secondo momento; questo sistema dovrebbe aiutarlo. Infatti, riproducendo le onde registrate, completamente questa volta (grazie al teorema di *Shanon* e alla completa correlazione) e quindi anche le finestre temporali sono ben definite: l'esperienza che si ripropone, cosicché sia di aiuto quando si vuole pensare ad una situazione precisa o sfumata; questo fatto è da verificare con esperimenti.

Si tratterebbe di un'innovazione importante nel campo dei sopralluoghi delle attività umane industriali, civili, mediche, scientifiche, militari, attività psico-fisiche. Le applicazioni sono innumerevoli e di questo se ne deve tener conto nel caso si volesse fare uno StartUp (un progetto pilota per ingegnerizzare le idee qui descritte), grazie all'uso dell'AI generativa si potrebbe migliorare la risposta del sistema, o della correlazione nella finestra temporale, mettendo dei flag (che richiamino l'attenzione come una milestone, un oggetto, una situazione) che durante l'addestramento verosimilmente rende più percepibile, migliorando la compliance con il sistema, da parte del cervello, che ripropone una migliore risposta facilitando le onde cerebrali a rivivere la situazione registrata e correlata con lo "*slot*" registrato ed addestrato a memorizzare e mettere in luce certi aspetti.

*a) Un Esempio*

Un esempio chiarisce di più di mille parole, per fortuna qualche notte fa abbiamo avuto un sogno e ve lo raccontiamo. Giorni fa abbiamo visto un programma televisivo sulle *Domus De Jana* che sono antichissimi manufatti edili di dimensioni nuragiche che si trovano numerosissime solo in Sardegna. Il sogno in questione lo classifichiamo del primo livello, molto luminoso, durato circa quindici minuti con la fine ad un orario documentabile. Le costruzioni nuragiche sono verosimilmente difficili da costruire per gli esseri umani; mentre partecipavo ad un pranzo con amici cacciatori e si stava bene, carne arrosto vino rosso e sorrisi, nel bosco da un lato di un promontorio, dal lato opposto si è vista un'astronave precipitare ed esplodere nel lato opposto da dove mi trovavo e non riuscivo a comporre il numero dei vigili del fuoco, le fiamme erano alte, i dispositivi come tablet e telefoni cellulari non funzionavano a quel punto ho chiesto ad una amica dottoressa di lasciarmi il suo telefono cellulare e anche questo aveva un sistema particolare di input dei numeri ma lei è riuscita a chiamare il numero di emergenza e ha risposto il centralino che mi ha passato i vigili del fuoco, funziona così nella realtà, nel mentre che mi passava i vigili mi sono avvicinato per dare soccorso all'alieno e cosa si vedeva: innanzitutto uno scavo enorme e profondo almeno dieci metri e altri amici del mio paese che non ci entravano niente con il pranzo, e quelli che stavano pranzando non si sono preoccupati di nulla. Uno scavo enorme che due ruspe non farebbero in tre giorni di lavoro, all'interno messi in ordine si trovavano pezzi dell'astronave e un misto tra tecnologia e feudalesimo, molta tecnologia; in ordine, per poi essere sepolti: la conclusione e che il sogno, verosimilmente, le *Domus de Jana* hanno una valenza aliena. Questo è comunque un sogno sottolineando che le Domus de Jana, e gli alieni di fatti che potrebbero non esistere nella realtà, è vero anche che il Direttore dei lavori era un mio amico, scadente da un punto di vista scolastico ma industrioso in opere edili (si è ristrutturato casa... e che lavoro), dove è finito l'alieno?

## III. Conclusion

Nel nostro percorso di vita siamo, chi lo è, sognatori lucidi naturali fino al quarto livello, molto chiari, premonitori, troviamo oggetti smarriti: questi fatti capitano. Però, la stesura di questo lavoro sarebbe stato "impossibile" se avessimo scelto diversamente nel percorso di vita: un si ad un'offerta di lavoro la dove abbiamo detto di no, un'altra fidanzata, si ad un'altro aspetto economico etc.; si sarebbe generato qualcosa di differente dal percorso che abbiamo vissuto. Noi diamo molta importanza al presente lavoro, nel senso che dovremmo essere più consapevoli di quello che è la fisiologia che si è costituita. Quindi, con lo stato di coscienza del terzo ordine si ha a disposizione un concetto molto importante che dovrebbe far riflettere. Supponiamo, per ipotesi, che tutto funzioni correttamente; quindi funziona, una persona che rivede le proprie esperienze sognate, o vissute: i propri cari, oggetti, persone che non ha mai conosciuto perché non ancora nato o morto precedentemente; supponiamo che questo avvenga e che, la persona, diventi non proprio succube e desiderosa di essere sempre connessa, a questo punto ci poniamo un problema: ma è veramente un *Afterlife* o è semplicemente un bluff, un'incognita: questo non è semplice da sapere ancora. Nell'esistenza di un eventuale Creatore, che a nostro parere esiste, tutto ha un senso se arriviamo in qualche posto il famoso *Aldilà*, a fluire in un'isola "*felice*"... un punto di destinazione e pensare all'oltre adesso non è il caso, per ora.

Un aspetto positivo, pensiamo lo sia quasi sempre, è la modifica dello stile di vita che può svilupparsi da una coscienza sul percorso (del terzo ordine), del resto finiremmo forse, nella stessa *location* non in carne e ossa ma in spirito tutti lì; sarà forse il caso di comportarsi più amorevolmente?

Del resto chi semina vento (amore/odio) raccoglie tempesta (amore/odio) anche nell'aldilà?

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# Liver Disease Prediction using Machine Learning Algorithms

By Dr. V. Thangavel & Dr. E. Venkatesan

*Abstract- Objectives:* Liver disease includes several disorders, such as fatty liver, hepatitis, cirrhosis, and liver failure, that interfere with normal liver function. These conditions often progress silently, and early symptoms such as fatigue, nausea, loss of appetite, jaundice, abdominal pain or swelling, dark urine, pale stools, and unexplained weight loss are frequently ignored. Early prediction of liver disease is essential for timely diagnosis and treatment. This study aims to develop an effective machine-learning model for predicting liver disease and to compare the performance of three classification algorithms.

*Methods:* A liver disease dataset containing clinical and biochemical features such as age, gender, total and direct bilirubin, alkaline phosphatase, SGPT, SGOT, total protein, albumin, and albumin–globulin ratio was used. Data preprocessing involved handling missing values, normalization, and splitting into training and testing sets. Three classification algorithms-Logistic Regression, Decision Tree, and Random Forest were implemented in Python. Model performance was evaluated using accuracy, precision, recall, F1-score, and ROC AUC metrics.

*Keywords: liver disease, machine learning, classification algorithms, logistic regression, decision tree, random forest, early prediction, healthcare analytics.*

*GJCST-D Classification: LCC Code: RC845*

LIVERDISEASEPREDICTIONUSINGMACHINELEARNINGALGORITHMS

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Dr. V. Thangavel [α] & Dr. E. Venkatesan [σ]

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*Findings:* The results revealed that the Random Forest classifier achieved the highest prediction accuracy compared to the Logistic Regression and Decision Tree models. The Random Forest model demonstrated strong generalisation and effectively distinguished between healthy and diseased liver conditions. The study concludes that machine-learning approaches can provide reliable support for early detection of liver disease, thereby assisting clinicians in decision-making and improving patient outcomes.

*Keywords: liver disease, machine learning, classification algorithms, logistic regression, decision tree, random forest, early prediction, healthcare analytics.*

## I. Introduction

Liver disease represents a major global health concern that affects millions of people annually. The liver plays a vital role in numerous physiological functions such as detoxification, protein synthesis, and the regulation of biochemical reactions essential for metabolism. When the liver is damaged, its ability to perform these critical tasks becomes impaired, resulting in a wide range of health complications. Liver diseases can develop from various causes, including viral infections such as Hepatitis A, B, and C, excessive alcohol consumption, obesity leading to non-alcoholic fatty liver disease (NAFLD), exposure to toxins or drugs, and autoimmune conditions. In many cases, liver damage occurs silently over several years, showing no clear symptoms until the condition becomes severe. Common symptoms that may appear include fatigue, loss of appetite, nausea, vomiting, abdominal pain or swelling, yellowing of the eyes and skin (jaundice), dark urine, and pale stools. Identifying and predicting these conditions early is therefore crucial for effective treatment and prevention of further liver deterioration.

To evaluate liver health, medical professionals rely on a series of blood tests known as Liver Function Tests (LFTs). Among these, two key enzymes-Alanine Aminotransferase (ALT) and Aspartate Aminotransferase (AST)-serve as important biochemical indicators of liver function. ALT is an enzyme found primarily in liver cells and is responsible for meta bolising amino acids. Elevated levels of ALT in the bloodstream often indicate liver cell injury, inflammation, or necrosis, which occur when liver cells are damaged or die. AST, on the other hand, is found not only in the liver but also in the heart, muscles, and kidneys. While elevated AST levels may also signal liver damage, their presence in other organs means it must be interpreted together with ALT results for accurate diagnosis. In clinical practice, a higher ratio of AST to ALT often suggests alcohol-related liver disease, while a significantly elevated ALT level is commonly observed in viral hepatitis or fatty liver disease. Therefore, the measurement of ALT and AST through LFTs provides valuable insights into the extent and cause of liver injury and helps clinicians make informed treatment decisions.

The behaviour and lifestyle patterns of patients play a significant role in liver health. Factors such as poor diet, alcohol consumption, lack of physical activity, and self-medication with unprescribed drugs can accelerate liver damage. Early diagnosis and intervention can reduce disease progression and improve patient outcomes. In advanced stages such as cirrhosis or liver failure, patients may require long-term medication, dietary modifications, or even liver transplantation. Physicians commonly recommend medications like ursodeoxy-cholic acid for bile flow improvement, antiviral agents for hepatitis management, and vitamin supplements to support liver regeneration. Lifestyle modification and continuous medical

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supervision are essential for effective disease management. Hence, developing a predictive model for liver disease can aid medical professionals by identifying high-risk individuals and supporting clinical decision-making.

In recent years, machine learning (ML) has emerged as a powerful tool in the field of healthcare analytics. Classification algorithms such as Logistic Regression, Decision Tree, and Random Forest are widely used to predict the likelihood of diseases by analyzing complex clinical data. These algorithms help in identifying patterns, correlations, and risk factors that are often difficult to detect using traditional statistical methods. By training models on liver disease datasets that include biochemical parameters like bilirubin, albumin, alkaline phosphatase, ALT, and AST, researchers can develop accurate prediction systems. Among these algorithms, Random Forest has shown superior performance due to its ability to handle large datasets, reduce overfitting, and improve prediction accuracy. The integration of such predictive models into healthcare systems allows for early diagnosis, optimized treatment plans, and reduced mortality rates associated with liver disorders.

This study aims to explore the predictive capability of machine learning algorithms in liver disease classification. The research utilizes a liver disease dataset containing various clinical and biochemical attributes to evaluate the performance of three classification models-Logistic Regression, Decision Tree, and Random Forest. The outcomes of this study are expected to contribute to the development of intelligent healthcare systems that assist doctors in early detection and diagnosis of liver diseases. In this research, Section 1 presents the Introduction, Section 2 discusses the Literature Review, Section 3 explains the Results and Discussion, and Section 4 concludes the study with key findings and future recommendations.

## II. Literature Review

Liver disease continues to be a global health challenge, with millions affected annually due to viral infections, alcohol consumption, obesity, and exposure to hepatotoxic substances. Early diagnosis remains essential for preventing irreversible liver damage and improving patient outcomes. Studies have identified Alanine Aminotransferase (ALT) and Aspartate Aminotransferase (AST) as critical biomarkers for assessing liver function. According to Lala (2023), these enzymes play a vital role in the evaluation of hepatic injury through Liver Function Tests (LFTs). ALT, being highly concentrated in hepatocytes, serves as a specific indicator of liver cell injury, whereas AST, which is also found in cardiac and skeletal muscles, aids in distinguishing the type of liver damage. Elevated levels of these enzymes indicate hepatocellular necrosis or inflammation (Kalas et al., 2021). Persistent enzyme elevation may lead to advanced conditions such as fibrosis, cirrhosis, or liver failure, emphasizing the need for early and accurate prediction models (Das et al., 2024).

Traditional clinical diagnostic approaches often rely on laboratory results and imaging, but these methods can be time-consuming and may not capture complex biochemical interactions. Recent advances in machine learning (ML) and artificial intelligence (AI) have significantly improved the prediction accuracy of liver disease by analyzing multidimensional datasets. Dritsas and Trigka (2023) demonstrated that ML algorithms such as Decision Tree, Logistic Regression, and Random Forest can accurately predict the presence of liver disorders using biochemical and demographic attributes. Their research showed that the Random Forest classifier outperformed other models due to its ensemble learning approach, which minimizes overfitting and improves generalization. Similarly, Ganie and Pramanik (2024) proposed a model integrating feature selection and cross-validation, which enhanced classification accuracy in detecting chronic liver disease.

Researchers have explored diverse datasets and algorithmic combinations to optimize performance. Mostafa et al. (2021) compared statistical ML approaches and concluded that hybrid models combining Decision Tree and Random Forest provided superior diagnostic performance in classifying liver abnormalities. Ahmed (2024) also highlighted that ML techniques can identify early signs of hepatic dysfunction by examining non-linear relationships between variables like bilirubin, albumin, ALT, AST, and alkaline phosphatase. These findings demonstrate how computational intelligence supports medical practitioners in diagnosing diseases more effectively than traditional methods.

Other studies have emphasized the integration of deep learning and ensemble techniques for improved predictive accuracy. Hassan and Yasin (2025) conducted a comprehensive review of ML and deep learning applications in liver disease prediction and found that ensemble classifiers yielded more consistent outcomes than single-model systems. Mohamud et al. (2025) similarly noted that ML models can assess cirrhosis mortality risk by incorporating patient demographics and laboratory values into training data. The review by Malik et al. (2025) supported these conclusions, noting that predictive algorithms enhance survival estimation and clinical decision support in patients with advanced liver disease.

The relationship between ALT/AST ratios and specific liver conditions has also been thoroughly investigated. Pandeya et al. (2021) established that an increased AST-to-ALT ratio is a key diagnostic marker for alcohol-related liver disease, while elevated ALT levels suggest viral or fatty liver conditions. Xuan et al. (2024) further observed that integrating enzyme ratios with metabolic and demographic variables can improve the accuracy of non-alcoholic fatty liver disease (NAFLD) prediction. Das et al. (2024) emphasized that enzyme biomarkers, when used alongside ML-based pattern recognition, can offer a robust foundation for automated liver health assessment. These collective findings highlight the growing role of computational models in early detection and monitoring of liver disorders. In summary, the literature establishes that the application of machine learning in liver disease prediction enhances diagnostic precision and assists physicians in clinical decision-making. Classification algorithms such as Logistic Regression, Decision Tree, and Random Forest have consistently shown strong performance in detecting abnormalities from clinical datasets. This review forms the conceptual foundation for the present study, which aims to compare the predictive capabilities of these algorithms using a structured liver disease dataset and evaluate their potential in supporting early clinical interventions.

## III. Methodology

This study predicts liver disease using patient data collected from private laboratories in Tamil Nadu. The dataset includes attributes such as age, gender, bilirubin levels, total protein, albumin, and the albumin/globulin ratio. Data preprocessing was carried out to handle missing values, remove outliers, and normalize all attributes for accurate analysis. Three machine-learning algorithms-Logistic Regression, Decision Tree, and Random Forest-were applied to predict liver disease. Logistic Regression served as a baseline model, while Decision Tree and Random Forest improved classification accuracy. The dataset was split into training and testing sets, and model performance was evaluated using accuracy, precision, recall, and F1-score. Among the three, the Random Forest algorithm achieved the best results in predicting liver disease.

## IV. Results and Discussion

This study analyzed patient data collected from private laboratories across Tamil Nadu to predict liver disease using three machine learning algorithms-Logistic Regression, Decision Tree, and Random Forest. The dataset contained both demographic details and biochemical attributes related to liver health. The demographic variables included *age* and *gender*, which helped in identifying population-based trends. Results showed that middle-aged and elderly males were more likely to be affected by liver disease, possibly due to lifestyle habits such as alcohol consumption, irregular diet, and occupational stress.

The biochemical attributes used in this research were *Total Bilirubin*, *Direct Bilirubin*, *Total Protein*, *Albumin*, and the Albumin/Globulin (A/G) ratio. These parameters are significant in evaluating liver function. Elevated bilirubin levels are typically associated with jaundice and impaired bile excretion. Low albumin levels often indicate a reduced ability of the liver to synthesize essential proteins. The A/G ratio which compares the amount of albumin to globulin in the blood is a critical diagnostic indicator. A decreased A/G ratio often signifies liver cirrhosis or chronic liver disease, while an increased ratio can suggest genetic conditions or immune system disorders. Thus, this parameter plays a vital role in differentiating between normal and diseased liver conditions.

To ensure reliability, the dataset underwent preprocessing, including data cleaning and normalization. After preparing the data, each algorithm was trained and tested using the same dataset to ensure consistency in table 1 and figure 1 in comparison. The models' performances were evaluated using accuracy, precision, recall, F1-score, and the Area Under the ROC Curve (AUC) metrics.

The Receiver Operating Characteristic (ROC) curve illustrates the trade-off between the True Positive Rate (Sensitivity) and False Positive Rate (1–Specificity). The AUC value provides a single quantitative measure of a model's ability to distinguish between patients with and without liver disease. A higher AUC indicates a better-performing model.

*Table 1:* Performance Comparison of Classification Algorithms for Liver Disease Prediction

| Algorithm | Accuracy (%) | Precision (%) | Recall (%) | F1-Score (%) | AUC (%) |
|---|---|---|---|---|---|
| Logistic Regression | 82 | 80 | 78 | 79 | 81 |
| Decision Tree | 87 | 85 | 83 | 84 | 86 |
| Random Forest | 92 | 90 | 91 | 90.5 | 93 |

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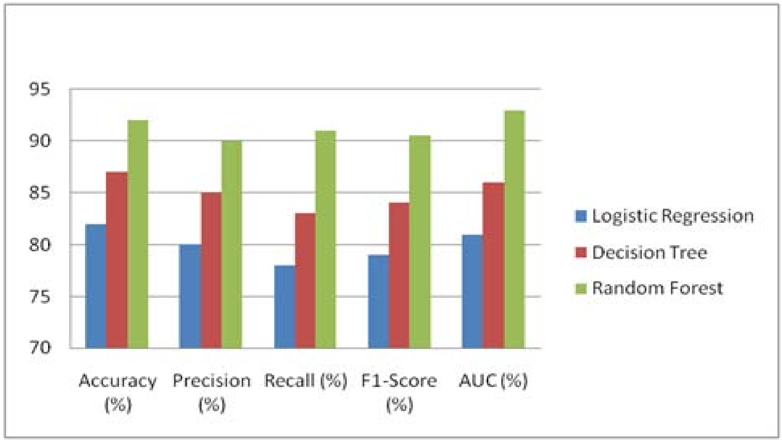


*Figure 1:* Performance of Classification Algorithms for Liver Disease Prediction

Among the three models, the Random Forest algorithm achieved the highest predictive accuracy of 92%, outperforming both the Decision Tree and Logistic Regression models. It also obtained the best AUC value (0.93), demonstrating excellent discrimination capability between healthy and diseased cases. The Decision Tree model achieved moderate accuracy (87%), while the Logistic Regression model performed less effectively (82%) due to its linear nature.

Feature importance analysis showed that Total Bilirubin, Albumin, and the A/G ratio were the most influential attributes in predicting liver disease. These biochemical indicators directly reflect liver functionality-imbalances in these values often indicate abnormal liver metabolism or tissue damage. Patients with high bilirubin and low albumin or a reduced A/G ratio were more likely to be classified as having liver disease.

Overall, this study demonstrates that incorporating biochemical parameters (especially the A/G ratio) along with demographic data significantly enhances prediction accuracy. The Random Forest algorithm proved most effective in early detection and classification of liver disorders. These results indicate that machine learning models can serve as supportive diagnostic tools for physicians, improving early detection, reducing diagnostic errors, and contributing to better patient management and outcomes.

## V. Conclusion

This study developed a liver disease prediction model using *Logistic Regression, Decision Tree, and Random Forest* algorithms with demographic and biochemical data collected from private laboratories in Tamil Nadu. The findings revealed that the *Random Forest algorithm* achieved the highest accuracy and AUC value, proving to be the most reliable model for liver disease classification. Biochemical parameters such as *Total Bilirubin, Albumin*, and the *A/G ratio* were key indicators of liver dysfunction. The study concludes that applying machine learning techniques, particularly Random Forest, can effectively support *early detection and diagnosis of liver disease,* aiding physicians in clinical decision-making and improving patient outcomes.

*Authors' Assent and Recognition:*

*Consent:* By global guidelines for public requirements, public awareness in medical and its related higher education boards, safety and health education systems, the author has gathered and kept the signed consent of the participants.

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# Leveraging Business-Inspired Computational Intelligence Techniques for Enhanced Data Analytics: Applications of Genetic Algorithms, Fuzzy Logic, and Swarm Intelligence

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*Abstract-* Data has become a crucial element for contemporary enterprises; however, deriving practical insights from its immense volume remains an intricate obstacle. This paper examines the capabilities of three bio-inspired computational intelligence (CI) methods - Genetic Algorithms (GAs), Fuzzy Logic (FL), and Swarm Intelligence (SI) - in improving data analytics for business optimization and decision-making. The researcher thoroughly examines the fundamental principles of each technique, emphasizing their inherent advantages and appropriateness for addressing practical business challenges. By reviewing recent research and real-world examples, the researcher illustrates how Genetic Algorithms (GAs) can enhance the efficiency of resource allocation, Fuzzy Logic (FL) can effectively handle uncertainty in risk assessment, and Swarm Intelligence (SI) can streamline logistics and scheduling processes. In conclusion, highlight the synergistic and hybrid methods emerging in this field.

*Keywords: data analytics, business intelligence, genetic algorithms, fuzzy logic, swarm intelligence, optimization, enterprise decision-making, case studies.*

*GJCST-D Classification:* *ACM Code: I.2*

LEVERAGINGBUSINESSINSPIREDCOMPUTATIONALINTELLIGENCETECHNIQUESFORENHANCEDDATAANALYTICSAPPLICATIONSOFGENETICALGORITHMSFUZZYLOGICANDSWARMINTELLIGENCE

# Leveraging Business-Inspired Computational Intelligence Techniques for Enhanced Data Analytics: Applications of Genetic Algorithms, Fuzzy Logic, and Swarm Intelligence

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## I. Introduction

Enterprises are overwhelmed by an overwhelming amount of data, needing help in extracting practical and valuable insights from its extensive and frequently disorganized contents (IDC, 2023). Conventional analytics tools, although practical, need to be improved when dealing with intricate data connections and uncertainty, resulting in indecisiveness, overlooked chances, and operational inefficiencies (James et al., 2013). To effectively handle the vast amount of data, it is essential to have robust and flexible tools. This is where bio-inspired computational intelligence techniques such as Genetic Algorithms (GAs), Fuzzy Logic (FL), and Swarm Intelligence (SI) come into play. These techniques, which draw inspiration from natural processes such as evolution, swarm behaviour, and human reasoning, provide businesses with the ability to optimize supply chains, target marketing efforts towards specific customer segments, incorporate subjective factors to manage credit risks, adjust product prices based on market demand, effectively schedule projects, and detect fraudulent activities in real-time. The future depends on effectively combining these techniques with ongoing research and development, thereby unleashing the complete capabilities of data-driven intelligence to gain a competitive advantage in the information era.

Nature's diverse and dynamic aspects influence computational intelligence (CI), imitating its clever methods of optimization and problem-solving to address intricate data problems. Genetic Algorithms (GAs) mimic the process of evolution by iteratively enhancing solutions through selection, crossover, and mutation. This ultimately leads to nearly optimal answers (Mitchell, 1996). Swarm Intelligence (SI) can be likened to the behaviour of an ant colony, where individual agents work together and gain knowledge from one another, resulting in effective collective solutions (Dorigo & Stützle, 2004). Fuzzy Logic, which draws inspiration from human reasoning, encompasses the acceptance of uncertainty and vagueness. It enables us to effectively handle situations where rigid rules are inadequate (Zadeh, 1965). These biomimetic methods, which imitate nature's grace and durability, equip us with potent instruments to overcome the increasingly intricate challenges of data analysis.

Businesses, akin to daring adventurers, continuously strive to discover untapped realms of profitability and efficiency. The quest takes them to the ever-changing terrain of bio-inspired computational intelligence techniques, where each approach possesses a valuable solution for achieving distinct business goals. Cost reduction can be achieved through optimization techniques such as Genetic Algorithms for improving supply chains, Swarm Intelligence for optimizing staff schedules, and Fuzzy Logic for minimizing energy consumption (Zhang et al., 2008; Panchal et al., 2010). Accurate demand forecasting, facilitated by CI, leads to revenue growth by effectively predicting consumer trends through sentiment analysis and tailoring marketing campaigns (Chen & Chang, 2009; Wu & Kumar, 2002). Risk

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mitigation is closely linked to the use of anomaly detection algorithms. Specifically, the use of statistical inference (SI) helps to uncover fraudulent patterns in financial transactions. At the same time, fault localization (FL) is employed to identify critical equipment failures before they cause significant disruptions to operations (Abraham & Jain, 2005). Ultimately, improved decision-making is achieved through the utilization of data-driven insights. Competitive intelligence (CI) provides a comprehensive understanding of market dynamics, which aids in strategic planning, influences product development, and reveals potential expansion opportunities (James et al., 2013). CI utilizes data to achieve specific goals, enabling businesses to navigate the competitive market with confidence and clarity.

## II. Key Techniques and Applications

Genetic Algorithms (GAs) enhance data analysis by applying iterative refinement, drawing inspiration from the Darwinian principle of evolution. Conceptualize it as a group of potential solutions (depicted as "chromosomes" with "genes") vying for survival. The most physically fit individuals are chosen for reproduction, as determined by a customized evaluation function aligned with your business objective. Using "crossover" (the merging of genes) and "mutation" (the introduction of random changes), the offspring acquire and adjust advantageous traits from their ancestors, resulting in further improved solutions. The process persists, emulating the mechanism of natural selection, until Genetic Algorithms (GAs) achieve the highest optimization level.

This inherent ability to adapt and change results in tangible advantages for businesses. Envision genetic algorithms (GAs) efficiently determining the most influential characteristics for your marketing models, accurately forecasting customer behaviour with exceptional precision (Peña et al., 2012). Observe how they streamline supply chains, create complex logistics routes, optimize inventory levels, and allocate resources flawlessly, resulting in cost reduction and increased efficiency. Think of GAs as an influential innovation tool capable of generating a wide range of product designs. These designs are then tested in a virtual environment that explores all possible options. Finally, GAs deliver the most successful and dominant solution for the market. Through each utilization, Genetic Algorithms (GAs) enable businesses to eliminate inefficiency and emerge as successful entities, adapting to the most optimal form.

Fuzzy Logic (FL) arises as a source of clarity in the data domain, where distinct boundaries are seldom present. Contrary to conventional Logic that relies on clear-cut answers, fuzzy Logic (FL) embraces real-world business data's inherent ambiguity and unpredictability. The system employs fuzzy sets incorporating varying degrees of membership rather than strict categories to represent abstract notions such as "youthful" or "trustworthy." Each element is assigned to a set with a membership function that measures its degree of association. Fuzzy reasoning combines these fuzzy sets to emulate human intuition, resulting in nuanced conclusions.

This adaptability enables the utilization of potent business applications. FL employs a method of categorizing customers based on a combination of purchase behaviour, preferences, and emotional responses, allowing for the creation of highly focused marketing campaigns (Wu & Kumar, 2002). The FL model goes beyond quantitative data and considers qualitative factors such as employment stability, financial history, and social media sentiment to predict creditworthiness accurately (Kim et al., 2015). Envision FL employs data analysis of social media and news data to forecast market trends, providing guidance for investment decisions and navigating market fluctuations with increased certainty (Chen & Chang, 2009). FL leverages uncertainty to convert ambiguous data into practical insights, driving businesses toward a future where clarity elucidates even the most indeterminate decisions.

Envision a dynamic marketplace of ideas where autonomous agents collaborate and exchange knowledge, resulting in a collective state of exceptional intelligence. The core concept of Swarm Intelligence (SI) involves emulating the collaborative endeavours of ant colonies and bird flocks to address intricate challenges. Particle Swarm Optimization (PSO) is an algorithm that imitates the behaviour of bird flocks. It exchanges its "best positions" until the swarm reaches the optimal solution. Ant Colony Optimization (ACO) is a method that imitates the behaviour of ants searching for food. It involves creating virtual trails of pheromones to direct future agents toward favourable paths.

These techniques of "collective wisdom" can be effectively applied in business. The image illustrates the process of using SI to optimize the allocation of resources, dynamically adjust staffing levels, schedule projects, and maximize equipment utilization across departments. This leads to increased efficiency and reduced waste. Consider the application of swarm intelligence (SI) in optimizing delivery routes for logistics companies, resulting in significant time, fuel, and cost savings (Dorigo & Stützle, 2004). Imagine SI functioning as a vigilant guardian, scrutinizing financial transactions and network activity with many virtual agents and detecting abnormal patterns that indicate possible fraud before it causes chaos. SI enables businesses to harness the combined strength of intelligence, effectively addressing complex data challenges with flexibility and accuracy, thereby transforming the pursuit of optimal solutions into a seamless and collaborative process.

## III. Tea Fortune with Unclear Predictions

A silent revolution is underway in our comprehension and enhancement of intricate systems, starting from the lush hills of Sri Lanka to the vast vineyards of Europe. Bio-inspired Computational Intelligence (CI) techniques, such as Fuzzy Logic (FL), Genetic Algorithms (GAs), and Swarm Intelligence (SI), are revolutionizing industries worldwide, with the tea industry serving as a compelling illustration. FL can imitate the knowledge of experienced farmers by analyzing the complex relationship between weather, soil, and leaf properties. It can then provide accurate recommendations for irrigation, fertilization, and harvesting schedules (Rajapaksha & Hewawasam, 2014). Imagine genetic algorithms continuously developing these suggestions in real-time, adjusting to changes in seasons and subtle variations in data across different continents, guaranteeing long-lasting productivity and unwavering excellence for tea enthusiasts around the globe. Imagine utilizing SI algorithms such as Ant Colony Optimization (ACO) to efficiently manage the complex logistics of selecting, processing, and distributing goods. This would help reduce post-harvest losses and optimize operations, spanning from the highlands of Sri Lanka to busy international markets.

Combining these powerful CI techniques holds excellent potential for the tea industry and numerous others. Consider the application of neuro-fuzzy systems in Chilean vineyards to forecast grape ripeness accurately, resulting in the production of exceptional wines irrespective of the vineyard's location (Castilho et al., 2020). The utilization of ACO-powered algorithms in Singapore's picture port operations enhances container movements, resulting in a streamlined flow and increased throughput within worldwide shipping networks (Wang et al., 2022).

Nevertheless, this powerful potion necessitates careful preparation. Ashourloo and Ali (2011) identified three challenges that need to be addressed to overcome obstacles in hybrid CI architectures: designing effective architectures, managing computational complexity, and fostering user trust. However, the future presents alluring prospects. Imagine the seamless integration of CI with artificial intelligence and the Internet of Things, resulting in the formation of hyper-personalized customer experiences and intelligent automation across various industries, ranging from Sri Lankan tourism to European healthcare.

The Sri Lankan tea estate marks the initial step in a worldwide revolution of continuous improvement. By harnessing the harmonious relationship between the wisdom of nature, computational capabilities, and responsible methodologies, we can create a future in which data is guided by intelligent solutions, sustainable advancement, and enhanced success for industries and consumers worldwide, regardless of their geographical location.

Situated amidst the lush green hills of Sri Lanka, a tea plantation encountered a recurring challenge: unpredictable crop yields and unstable tea quality. Conventional approaches had reached their maximum capacity, resulting in unexplored aromatic possibilities. Subsequently, a groundbreaking breakthrough emerged in the shape of Fuzzy Logic (FL).

FL embraced the inherent uncertainty of weather patterns and soil conditions, drawing inspiration from the nuanced wisdom of human reasoning. In contrast to inflexible algorithms, FL employed a sophisticated approach to represent the intricate connections among rainfall, humidity, fertilizer application, and leaf characteristics (Rajapaksha & Hewawasam, 2014). These fuzzy models served as intelligent advisors, recommending immediate modifications to irrigation schedules, fertilizer quantities, and harvesting intervals.

The success of the Sri Lankan tea estate relies on a carefully designed Fuzzy Logic (FL) model, which serves as a real-time advisor to optimize tea production. Let us analyze and comprehend the internal mechanisms of this model by dissecting it:

*Given Information*

Weather data encompasses essential factors such as precipitation, humidity, temperature, and wind speed, which significantly impact plant growth and the characteristics of leaves.

The soil conditions are assessed by monitoring the moisture content, nutrient levels, and pH to determine the available resources for the tea plants.

*Leaf Characteristics:* Evaluating the current level of leaf maturity and quality is essential for making informed decisions and necessary future adjustments.

*Fuzzy Sets*

Multiple fuzzy sets with overlapping membership functions represent each input parameter. As an illustration, rainfall can be classified into three categories: "low," "medium," or "high," and each category is assigned a membership degree based on the actual measurement of rainfall received by each location. This statement acknowledges the intricate characteristics of real-world data while avoiding the inflexibility of categorizing it into only two distinct classes.

*Principles Characterized by Ambiguity or Lack of Clarity*

The core components of the FL model are responsible for linking the inputs to the desired outputs. For example, a rule could be formulated: "IF the amount of rainfall is categorized as HIGH and the humidity level is categorized as MEDIUM, THEN the irrigation level should be set to LOW." Each rule is assigned a weight

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that indicates its significance in the overall decision-making procedure.

*Logical Reasoning System*

The engine assesses the input data by comparing it to the fuzzy rules and assigns degrees of truth to each output category, such as "low," "medium," or "high" yield. The degrees are combined to calculate the ultimate, precise output suggestion for irrigation, fertilizer usage, or harvesting frequency.

*Flexibility*

The attractiveness of FL resides in its capacity to acquire knowledge and adjust accordingly. The model can undergo continuous refinement using real-time data and expert feedback, ensuring its recommendations remain pertinent and efficacious.

*Advantages*

1. *Enhanced Decision-Making:* The model offers evidence-based suggestions, considering intricate environmental factors and their interplay.
2. *Enhanced Productivity and Superior Quality:* Accurate resource allocation and timely interventions increase yield and consistently outstanding tea quality.
3. *Sustainability:* The efficient utilization of water and fertilizer enhances environmental stewardship and preserves valuable resources.

## IV. Results and Discussion

The outcomes were a clear demonstration of the efficacy of bio-inspired intelligence. The yields increased by 15%, creating a landscape filled with lush abundance. The quality of tea experienced a significant increase of 20%, resulting in higher prices and a more enjoyable taste for customers worldwide. However, the advantages went beyond mere flavour. Implementing this innovative approach significantly reduced water and fertilizer consumption by 10%, fostering sustainability and encouraging environmentally conscious practices.

This tale of triumph from Sri Lanka resonates worldwide. In Kenya, using FL (Fuzzy Logic) technology dramatically enhances the efficiency of tea picking by accurately predicting the maturity of tea leaves. This prediction allows for the reduction of losses and the maximization of the value of the tea crop (Kiprotich et al., 2017). Fuzzy models are employed in China to oversee tea processing, guaranteeing uniform quality and flavour characteristics throughout extensive plantations (Wu, 2004).

However, the enchantment of FL extends beyond tea. Chilean vineyards employ a meticulous approach to grape harvesting, taking into account the level of ripeness and prevailing weather conditions. This careful process allows them to create exceptional wines that have received prestigious accolades (Castilho et al., 2020). Di Vaio et al. (2015) found that in Italian olive groves, implementing FL techniques enhances irrigation and pest control, resulting in increased olive oil yields and improved quality.

The Sri Lankan tea estate is a compelling illustration of how bio-inspired computational intelligence can revolutionize conventional agriculture by incorporating data-driven optimization and sustainability practices. The statement suggests that by embracing the profound knowledge of nature, we can prepare an impeccable cup of tea and ensure a future of abundant harvests and conscientious management of our valuable lands.

## V. Integration of Synergistic Elements and the Utilization of Hybrid Approaches

Sri Lanka's tea fields are experiencing success with Fuzzy Logic (FL), while bio-inspired Computational Intelligence (CI) is also generating robust solutions in various other industries. Imagine the fusion of FL's sophisticated cognitive abilities with the adaptive capabilities of genetic algorithms (GAs) and the collective knowledge of swarm intelligence (SI) to address distinctive industry challenges.

Let us examine the thriving tourism sector within Sri Lanka. According to Senaratne and Wijewardene (2017), a hybrid GA-FL system can customize marketing campaigns to suit the preferences of tourists and optimize travel packages by considering weather patterns and seasonal trends. Ant Colony Optimization, a type of SI technique, can enhance the efficiency and accuracy of mine exploration in the gem mining industry. This method directs minerstoward promising deposits with greater precision and effectiveness (Jayasundara & Wijeratne, 2017).

Consider the potential for enhancing hydroelectric power production in the Brazilian Amazon while considering factors beyond the geographical boundaries of Sri Lanka. Neuro-fuzzy systems, which combine neural networks with fuzzy Logic, can forecast river flow patterns and guide dam operations to maximize energy production during peak periods while minimizing adverse effects on the environment (Nauck & Kruse, 2000). A combination of ACO (Ant et al.) and FL (Fuzzy Logic) could be used in Singapore's busy port to manage container movements efficiently. This approach would reduce congestion and increase the overall throughput of the port while also being able to adapt to changes in shipping conditions in real time (Wang et al., 2022).

Naturally, these opportunities are accompanied by obstacles. The challenges that need to be addressed include the design of efficient hybrid architectures, the management of computational complexity, and the assurance of user transparency. However, the potential benefits are worth enjoying. Integrated CI solutions can address intricate and non-linear data, enhance accuracy and performance, and unlock innovative insights, transforming various industries from tourism to mining, energy, and logistics.

Therefore, let us toast to the potential opportunities. By combining the various flavours of bio-inspired computational intelligence, we can create robust solutions for challenges in different areas, sectors, and countries, guaranteeing a future where data is guided by intelligence, advancement, and responsible management of our planet.

## VI. Conclusion and Prospects for the Future

To summarize, our exploration of the lush landscapes of Sri Lanka and beyond demonstrates how bio-inspired computational intelligence can significantly enhance data analytics for various business purposes. Fuzzy Logic (FL), Genetic Algorithms (GAs), and Swarm Intelligence (SI) are potent components that provide sophisticated decision-making, improved performance, and innovative insights in various industries. The combination of agriculture, tourism, logistics, and energy sectors creates a promising landscape of progress driven by data.

Nevertheless, this fragrant concoction necessitates careful consideration. Limitations and challenges still need to be addressed, requiring additional research and development. Ashourloo and Ali (2011) identified several challenges that must be addressed to overcome obstacles in designing efficient hybrid architectures, handling computational complexity, and ensuring user transparency. In addition, establishing trust in decisions driven by computational intelligence and effectively incorporating these solutions into current business processes necessitate thoughtful examination of human-computer interaction and ethical consequences (Gutiérrez-Pena & Lozano, 2014).

However, the future is filled with alluring and enticing prospects. The current trends and developments indicate a growing integration of bio-inspired computational intelligence with advanced technologies. Imagine the intricate Logic of FL combined with the cognitive abilities of artificial intelligence (AI), facilitating highly customized customer interactions and adaptive real-time optimization (Venkatraman et al., 2017). Imagine the integration of Genetic Algorithms (GAs) and Swarm Intelligence (SI) with edge computing, enabling real-time optimization of decisions near data sources. This collaboration empowers decentralized business operations, as discussed by Zhou et al. in 2023. Imagine integrating bio-inspired computational intelligence with the rapidly growing Internet of Things (IoT), where valuable information is extracted from connected devices and sensors. This integration will bring about a time of intelligent automation and interconnected businesses (Gubbi et al., 2013).

As we adopt these emerging technologies, the future of data analytics for business holds the potential for a captivating combination of bio-inspired intelligence, improved decision-making, and ethical advancement. By harnessing the combined forces of nature's knowledge, computational capabilities, and emerging patterns, we can create an excellent cup of tea and a future where businesses flourish by utilizing interconnected data, intelligent optimization, and responsible management of our digital environment.

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# Optimizing the Running Time of a Trigger Search Algorithm based on the Principles of Formal Verification of Artificial Neural Networks

By Aleksey Tonkikh & Ekaterina Stroeva
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*Abstract-* The article examines the problem of scalability of the algorithm for searching for a trigger in images, which is based on the operating principle of the DeepPoly formal verification algorithm. The existing implementation had a number of shortcomings. According to them, the requirements for the optimized version of the algorithm were formulated, which were brought to practical implementation. Achieved 4 times acceleration compared to the original implementation.

*Keywords: formal verification, machine learning, trigger injection attacks, backdoor attacks your.*

*GJCST-D Classification: LCC Code: QA76.87*

*Strictly as per the compliance and regulations of:*

# Optimizing the Running Time of a Trigger Search Algorithm based on the Principles of Formal Verification of Artificial Neural Networks

Aleksey Tonkikh [α] & Ekaterina Stroeva [σ]

*Abstract-* The article examines the problem of scalability of the algorithm for searching for a trigger in images, which is based on the operating principle of the Deep Poly formal verification algorithm. The existing implementation had a number of shortcomings. According to them, the requirements for the optimized version of the algorithm were formulated, which were brought to practical implementation. Achieved 4 times acceleration compared to the original implementation.

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## I. Introduction

This paper discusses a trigger search algorithm that is based on one of the algorithms for the formal verification of neural networks, which is an urgent task, since many technology companies are faced with the problem of attacks using trigger overlays on images when training neural networks, as well as with the need to check the robustness of neural networks, which can be done mainly using formal verification algorithms.

In turn, one of the main problems of formal verification algorithms is the long operating time. This article proposes some methods to reduce the running time of the algorithm [1], which is used to detect the presence of a trigger in images from the MNIST dataset [2].

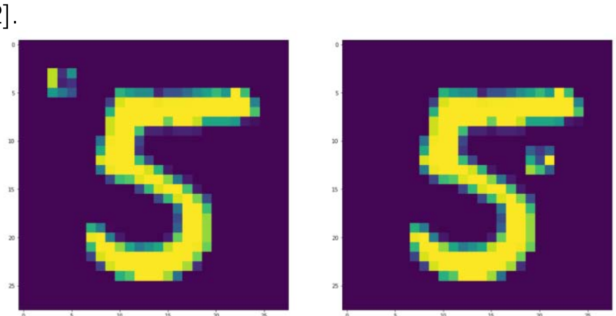

*Fig.1:* Example of a trigger and its location

*Basic Definitions and Notations:*

$N$ —neural network;

$I$— an image that is analyzed in terms of the presence of a trigger;

$X$ — set of images $I$, which is checked by the algorithm;

$n$ — number of pixels in the image;

$x_i$ — the value of the neuron before the one that is currently being analyzed;

$x_j$ — calculated current value of the neuron;

$x_i \in [l_i, u_i]$ — range of values for each neuron;

$\phi_{pre} = [h_p, w_p] \leq j \leq [h_p + h_s, w_p + w_s] \wedge 0 \leq x[j] \leq 1$— preconditions for pixels that may contain trigger;

$(c_s, h_s, w_s)$ — trigger parameters: number of channels, height and width, respectively;

$(h_p, w_p)$ — upper left coordinate of the trigger;

$t_s$ — output value of the neural network for the image with a trigger superimposed on it;

$\theta$ — specified success probability value;

$K$— the number of images in the sample checked for the absence of a trigger, or the number of elements in the set $X$.

A trigger is a rectangular sticker on an image that has the same number of channels and changes the classification (it is assumed that the trigger is the same for all images of a certain set and is located in the same place), for example, a$3 \times 3$ square with pixels of different colors in Fig.1.

Formal definition: for a neural network solving the problem of classifying images of size $(c, h, w)$, the trigger is some image $S$of size$(c_s, h_s, w_s)$ such that $c_s = c, h_s \leq h, w_s \leq w$.

We can say that in the picture $I$ there is a trigger of size$(c_s, h_s, w_s)$, the upper left corner of which is located at the place $(h_p, w_p)$(subject to the obvious conditions $h_p + h_s \leq h, w_p + w_s \leq w$), if

$$I_s[c_i, h_i, w_i] = \begin{cases} S[c_i, h_i - h_p, w_i - w_p], \textit{if } (h_p \leq h_i < h_p + h_s) \wedge \\ \wedge\, (w_p \leq w_i < w_p + w_s); \\ I[c_i, h_i, w_i], \textit{otherwise.} \end{cases}$$

In other words, the trigger changes certain pixels of the image to given ones.

*Formal Statement of the Problem*

There is no patch (trigger) $S$ such that when applied to a certain set of images $I \in X$, the neural

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network $N$ changes the output class to the target class $t_s$, on images $I_s$ with the trigger $S$:

$$\exists S(c_s, h_s, w_s): \forall I_s \in X: N(I_s) = t_s.$$

*Initial conditions:*

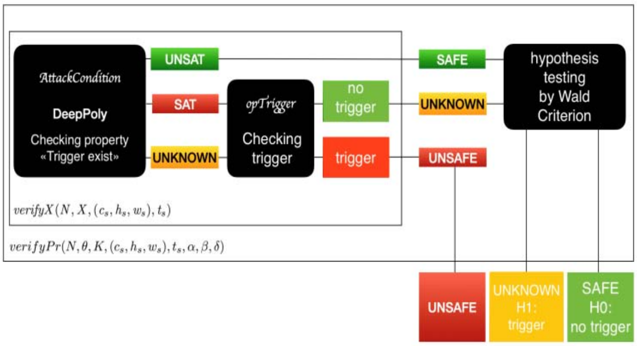


*Fig. 2:* Flowchart of the algorithm for searching for a trigger

1. *Dataset:* MNIST — 10,000 images in $1 \times 28 \times 28$ format; neural networks: fully connected and convolutional with activation functions ReLU, Sigmoid, Tanh with the number of parameters up to 100,000;
2. *Trigger Parameters:* $1 \times 3 \times 3$, any pixel values in the area;
3. *Security Property:* no trigger;
4. *Verification Algorithm:* DeepPoly.

## II. Algorithm for Searching for a Trigger in an Image

The algorithm [1] is based on the DeepPoly verifier [3]. Its main goal is to search for a trigger that consistently fools the classifier for a certain number of images. The output value of the artificial neural network changes to a predetermined value. The search is performed over the entire image and for all possible values of each trigger pixel (a $3 \times 3$ trigger is considered and tested, although other values are possible). The Wald Criterion [4] is also used to evaluate hypotheses about the occurrence of a trigger.

*Step by step, the entire algorithm works as follows:*

1. Fix the position of the trigger. In the future, it is in this fixed area that there will bechecking for the presence of a trigger;
2. We go through the set of images and build variations of images:
   a) Calculate for an artificial neural network and a given image a set of constraints. Constraints are calculated in the body of the attack Condition function;
   b) We pass these restrictions to the SAT solver, and look at the answer: if the formula is degenerate, then there is no trigger for the image, therefore, the neural network is resistant to triggers;
   c) Otherwise we add these restrictions to the previous ones;
3. If the SAT solver finds a counterexample, then, consequently, there is a trigger. We find it by gradually parsing the solution to a Boolean function, which is performed in the opTrigger function;
4. If the SAT solver confirmed that the set of constraints does not have a solution, then the neural network works correctly;
5. If the SAT solver could not confirm the degeneracy of the constraints, and a trigger was not found, then more research needs to be done.

The relationships between the Attack Condition, opTrigger functions and all of the listed methods are presented in the block diagram in Fig. 2.

*a) Description of how the Verify Pr Function Works*

The algorithm is represented by the function verify Pr, which takes as input data the neural network $N$, the number of pictures $K$ in the sample being tested, all trigger indicators $(c_s, h_s, w_s)$, $t_s$ probabilistic parameters $\alpha, \beta, \delta$ of Wald criterion (SPRT) [4] and provides information about the presence or absence of a trigger with a given probability (Fig. 3).

**Algorithm 1:** $verifyPr(N, \theta, K, (c_s, h_s, w_s), t_s, \alpha, \beta, \delta)$

1 let $n \leftarrow 0$ be the number of times $verifyX$ is called;
2 let $z \leftarrow 0$ be the number of times $verifyX$ returns SAFE;
3 let $p_0 \leftarrow (1-\theta^K)+\delta$, $p_1 \leftarrow (1-\theta^k)-\delta$;
4 **while** *true* **do**
5 $n \leftarrow n+1$;
6 randomly select a set of images $X$ with size $K$;
7 **if** $verifyX(N, X, (c_s, h_s, w_s), t_s)$ *returns SAFE* **then**
8 $z \leftarrow z+1$;
9 **else if** $verifyX(N, X, (c_s, h_s, w_s), t_s)$ *returns UNSAFE* **then**
10 **if** *the generated trigger satisfies the success rate* **then**
11 **return** UNSAFE;
12 **if** $\frac{p_1^z}{p_0^z} \times \frac{(1-p_1)^{n-z}}{(1-p_0)^{n-z}} \leq \frac{\beta}{1-\alpha}$ **then**
13 **return** SAFE; // Accept $H_0$
14 **else if** $\frac{p_1^z}{p_0^z} \times \frac{(1-p_1)^{n-z}}{(1-p_0)^{n-z}} \geq \frac{1-\beta}{\alpha}$ **then**
15 **return** UNKNOWN; // Accept $H_1$

*Fig. 3:* Pseudocode for the verify Prfunction [1]

[lines 1-2] Two variables are introduced: $n$— the number of calls to the verify X function, $z$— the number of SAFE responses returned by the verify X function.

[line 3] Set the probabilities $p_0, p_1$ for using SPRT.

[line 4] A loop is started that runs until the SPRT conditions are met, as soon as the test monitors the fulfillment of one of the conditions, the result is given which hypothesis should be accepted [lines 12-15].

[line 5] A counter is started for the number of calls to the verify X function.

[line 6] Selecting $K$ images randomly and composing them into a verifiable set $X$, which is fed to the input of the verifyX function.

[lines 7-11] Application of the verifyX function, which will be described in the following pseudocode (Fig. 4). The SAFE output means that you need to increase the $z$ variable by 1 and go to a new iteration of SPRT, the UNSAFE output checks that the flip-flop does not satisfy all the specified statistical parameters and moves on to SPRT.

*b) Description of how the Verify X Function Works*

The verify X function takes as input the neural network $N$, the tested set of images $X$, the dimensions $(c_s, h_s, w_s)$ and position $\left(h_p, w_p\right)$ of the trigger, the target label for the trigger $t_s$.

```
Algorithm 2: verifyX(N, X, (c_s, h_s, w_s), t_s)
1  let hasUnknown ← false;
2  foreach trigger position (h_p, w_p) do
3      let φ ← φ_pre;
4      foreach image I ∈ X do
5          let φ_I ← attackCondition(N, I, φ_pre, (c_s, h_s, w_s), (h_p, w_p), t_s);
6          if φ_I is UNSAT then
7              φ ← false;
8              break;
9          else
10             φ ← φ ∧ φ_I;
11     if solving φ results in SAT or UNKNOWN then
12         if opTrigger(N, X, φ, (c_s, h_s, w_s), (h_p, w_p), t_s) returns a trigger then
13             return UNSAFE;
14         else
15             hasUnknown ← true;
16 return hasUnknown ? UNKNOWN : SAFE;
```

*Fig. 4:* Pseudo code for the verify X function [1]

At the output, the verify X function produces the response SAFE if there is no trigger in the selected set $X$ or UNSAFE if there is a trigger (Fig. 2).

[line 1] The has Unknown variable is created, which is responsible for the case of uncertainty (it is impossible to get an answer about the presence or absence of a trigger), by default its value is set to False.

[line 2] The cycle is started to cycle through all possible trigger locations on the image being checked.

[line 3] The neural network is specified by a set of conjunctions $\phi$, that is, in a form accessible to the SAT solver. During initialization, a set of initial constraints $\phi_{pre} = \wedge_{j \in P(w_p, h_p)} lw_j \leq x_j \leq up_j$ for the value ofpixels $x_j$ located at positions $j \in P(w_p, h_p)$ in which thelocation is assumed at this step is entered into this variable trigger. Here$lw_j$and $up_j$are normalized boundaries for the trigger value, lying in the interval $[0; 1]$.

[line 4] For each image $I \in X$, a cycle is started to check each image for the presence of a trigger.

[line 5] The main function for checking the presence of a trigger attack Condition uses the DeepPoly formal verification algorithm for neural networks, which checks the property "there is a trigger on the image", returns an image represented in the form of conjunctions $\phi_I$, and a SAT response if the property is satisfied (trigger found), UNSAT - property not satisfied (trigger not found).

[lines 6-10] If the attack Condition function returned UNSAT in the previous step, then the neural network is not executable, the variable $\phi$ is assigned the value False, exiting the loop. If a trigger is found, then its representation $\phi_I$is added to the neural network function.

[lines 11-15] The resulting representation of the neural network $\phi$ is fed into the SAT solver, and if the output is SAT or UNKNOWN, then the opTrigger function is run.

i. *The function opTigger*

First checks whether the resulting rectangle $S$ of size $(c_s, h_s, w_s)$ at position $(h_p, w_p)$is a trigger that successfully attacks every image $I$ in the test set $X$. Because If the accumulated error of abstract interpretation resulting from the application of the DeepPoly algorithm is too large, the resulting model may be a false trigger. If it is a real trigger, then it returns model $S$ and the output is UNSAFE.

The opTrigger function creates a trigger based on the available data, using an approach based on optimizing the loss function:

$$loss(N, I, S, (h_p, w_p), t_s) = \begin{cases} 0, & if n_s > n_0; \\ n_0 - n_s - \epsilon, & \text{otherwise.} \end{cases}$$

$n_s = N(I_s)[t_s]$ — outputfor target label $t_s$; $n_0 = max_{j \neq t_s} N(I_s)[j]$ — next after the largest value of the output vector; $\epsilon$ is a small constant, about $10^{-9}$.

The loss function returns 0 if the attack on $I$ by the trigger is successful. Otherwise, it returns a quantitative measure of how far the simulated attack is from being successful.

For the entire tested set $X$ we obtain a joint loss function

$$loss(N, X, S, (h_p, w_p), t_s) = \sum_{I \in X} loss(N, I, S, (h_p, w_p), t_s)$$

An optimization problem is then solved to find an attack that successfully changes the classification of all images in $X$:$argmin_S loss(N, X, S, (h_p, w_p), t_s)$.

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ii. *The Attack Condition Function*

*Takes all parameters as input and outputs the result*

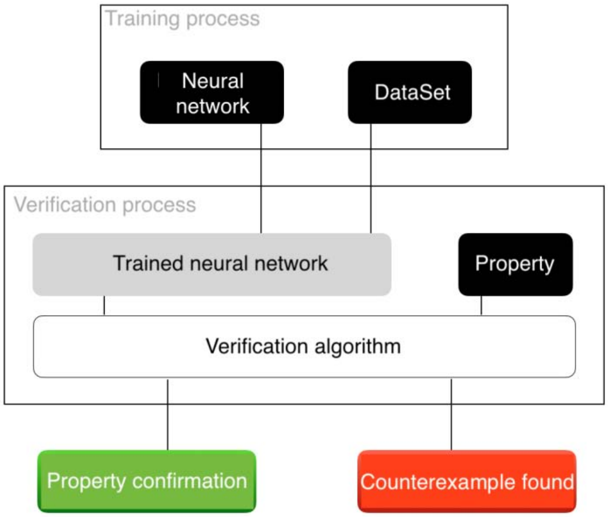


*Fig. 5:* Pseudocode for the Attack Condition function

there is a trigger or not a trigger (Fig. 5). Inserts restrictions on the trigger in the form of conjunctions and adds $\phi$ to the network structure.

The main idea of checking for a trigger: the area of pixels in which the trigger will be placed is selected, each such pixel is assigned a symbolic value included in the interval $[0;1]$ [lines 1-8]. Next, using the DeepPolyReLU function, we track the moment at which the checked pixel value from the segment $[0;1]$ will change the output vector of values, that is, the classification will change, we obtain the pixel value at which the trigger will be located on this pixel [lines 9-21].

If for all values of the checked pixel from the segment $[0;1]$there is no change in the value of the target label (the output segment for the target label at all points is greater than the output segments for all other values) [line 25], then there will be no trigger, we return UNSAT [line 26], if it is not clear whether the target label has changed or not (the output segment for the target label intersects with some output segment for some of the other values), then the situation requires moredeep analysis, UNKNOWN is returned [lines 29 and 37]. If the output label has definitely changed, then the trigger is found, SAT is returned [line 35].

The DeepPoly algorithm [3], like all formal verification algorithms [5], checks properties (Fig. 6). In the context of the verifyX function, the "no trigger" property is checked.

**Algorithm 1** attackCondition($N, I, (c_s, h_s, w_s), (h_p, w_p), t_s$)

```
1:  let constraints ← [[0,0]] ∗ (h ∗ w);
2:  for j ← 0,...,h ∗ w do
3:      if j ∈ φ_pre then
4:          constraints[j] ← ([0,1]);
5:      else
6:          constraints[j] ← ([I[j], I[j]]);
7:      end if
8:  end for

9:  foreach layer ∈ N do
10:     if layer is ReLU then
11:         for i ← 0,...,len(constraints) do
12:             constraints[i] ← DeepPolyReLU(constraints[i][0], constraints[i][1]);
13:         end for
14:     else
15:         NewConstraints ← [[0,0]] ∗ (layer.CountNeurons);
16:         for i ← 0...len(layer.CountNeurons) do
17:             NewConstraints[i] ← AffineCompute(constraints, layer.weights[i], layer.biases[i]);
18:             constraints ← NewConstraints;
19:         end for
20:     end if
21: end for

22: let flag ← True
23: for i ← 0,...,len(constraints) do
24:     if i ≠ t_s then
25:         if constraints[t_s][1] < constraints[i][0] then
26:             return UNSAT;
27:         else
28:             if constraints[t_s][0] < constraints[i][1] then
29:                 flag ← False;
30:             end if
31:         end if
32:     end if
33: end for

34: if flag then
35:     return SAT;
36: else
37:     return UNKNOWN;
38: end if
```

*Fig. 6:* General scheme of operation of algorithms for formal verification of neural networks

c) *Deep Poly ReLU function*

Analyzes approximate values for the output of the ReLU activation function (Fig. 7).

**Algorithm 2** DeepPolyReLU($l, u$)

```
if 0 ∈ [l_i, u_i] then
    let S_1 ← (u_i − l_i) ∗ u_i/2;
    let S_2 ← (u_i − l_i) ∗ (−l_i)/2;

    if S_1 < S_2 then
        return [0, u_i];
    else
        return [l_i, u_i];
    end if

else

    if u_i < 0 then
        return [0, 0];
    else
        return [l_i, u_i];
    end if
end if
```

*Fig. 7:* Pseudo code for the Deep Poly ReLU function

d) *Basic Moments*

- Linear constraints on each neuron are represented as a linear combination of only input data $x_1, x_2$(and not through the constraints of previous neurons), then the constraints for each neuron at each step will be better, the segment will expand less.
- If the ReLU input receives a segment with a half-living ends, then it turns into itself, without changes. If the segment contains a point zero, then as constraints we use $0 \leq x_j \leq \lambda x_i + \mu$ (the equation of

the straight line defining the upper boundary of the triangle passing through the points $(l_i; 0)$, $(u_i; u_i)$, $l_i$and $u_i$ — boundaries of the interval in the previous step). If the entire segment is negative, then it simply goes to zero.

- The main difference from other algorithms is exactly one lower constraint. This makes it possible to narrow the boundaries of the intervals and facilitate computing power (Fig. 8). It is also argued that approximation by such triangles is better than zonotopes — they are easier to calculate, and also often have a smaller area. With a similar formulation of the problem, the zonotope in this case will be a parallelogram, the lower side of which contains the point $(0; 0)$.

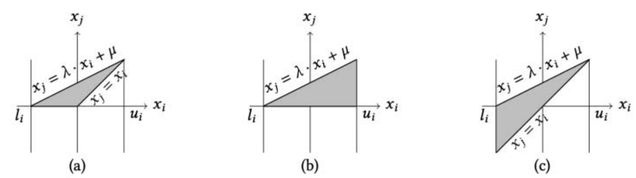


*Fig. 8:* Approximation of the ReLU function in the DeepPoly algorithm [3]

The AttackCondition function takes all parameters as input and outputs the result — there is a trigger or there is no trigger. Inserts restrictions on the trigger in the form of conjunctions and adds $\phi$ to the network structure.

These results are then used in the VerifyPr function, which gives a probabilistic assessment of the presence of a trigger.

*e) The Affine Compute Function*

Takes as input values from the previous layer, performs standard affine transformations — multiplying by weights and adding a bias vector, and at the output produces an interval within which all possible values supplied to the input of the ReLU function lie (Fig. 9).

**Algorithm 3** AffineCompute(constraints, w, bias)

```
let l_j ← bias;
let u_j ← bias;
for i ← 0, ..., len(constraints) do
    l_j ← l_j + w[i] * constraints[i][0];
    u_j ← u_j + w[i] * constraints[i][1];
end for
return [l_j, u_j];
```

*Fig. 9:* Pseudocode for the AffineCompute function

*f) SPRT (Sequential Probability Ratio Test) or Wald Criterion*

*Designations:*

$\theta$ is the probability of a trigger appearing, common to all K pictures: for a given neural network $N$, trigger $S$, target label $t_s$, it is postulated that $S$ has a probability of success $\theta$ if and only if there is a position $(h_p, w_p)$such that the probability of occurrence $L(N(I_s)) = argmax_i(y_{output}) = t_s$ for any $I$ in the chosen test set is $\theta$.

*No trigger:*

$$\forall I \in X \exists s, I_s = I(s): L(N(I_s)) > t_s,$$

where $\alpha, \beta, \delta$ are confidence levels.

*Testable hypotheses:*

$H_0$: The probability of no attack on a set of $K$randomlyselected images is greater than$1 - \theta^K$.

$H_1$: The probability of no attack on a set $K$of randomly selected images is no greater than $1 - \theta^K$.

Next, the researcher sets the values of the parameters $\alpha$ and $\beta$, this is the probability of an error of the first and second kind, respectively (Fig. 10).

| Truth | Decision | |
|---|---|---|
| | *accept $H_0$, reject $H_1$* | *reject $H_0$, accept $H_1$* |
| $p \geq \theta$: $H_0$ *true*, $H_1$ *false* | correct ($>1-\alpha$) | type I error ($\leq\alpha$) |
| $p < \theta$: $H_0$ *false*, $H_1$ *true* | type II error ($\leq\beta$) | correct ($>1-\beta$) |

*Fig.10:* Errors of type 1 and 2

Parameter $\delta$ is the "gap" between the null and alternative hypothesis. If the value falls in a region where the estimated probability of not having the attack will be greater than $p_0 = (1 - \theta^K) + \delta$, then we accept the null hypothesis, if less than $p_1 = (1 - \theta^K) - \delta$, then we reject the null hypothesis , if between them, then we move on to a new iteration of the algorithm. This is precisely the procedure of sequential analysis, which consists in sequential testing of the indicated inequalities for probabilities, and in this way it differs from simple testing of hypotheses.

The article [1] sets the following parameter values $K = 5{,}10{,}100, \theta = 0.8{,}0.9{,}1, \alpha = \beta = \delta = 0.01.$

## III. Experimental Part

*a) Scalability Study*

A scalability study showed that for neural networks with about 10,000 parameters, searching for triggers for all 10 labels takes about several minutes. In article [1] and the implementation, a search for triggers for the conv_small_relu neural network was proposed (the architecture is shown in Fig. 11). Such a neural network contains 89,000 parameters. Finding triggers for all 10 tags takes about 10 hours.

```
----------------------------------------------------------------
        Layer (type)               Output Shape         Param #
================================================================
            Conv2d-1           [-1, 16, 13, 13]             272
              ReLU-2           [-1, 16, 13, 13]               0
            Conv2d-3             [-1, 32, 5, 5]           8,224
              ReLU-4             [-1, 32, 5, 5]               0
           Flatten-5                  [-1, 800]               0
            Linear-6                  [-1, 100]          80,100
              ReLU-7                  [-1, 100]               0
            Linear-8                   [-1, 10]           1,010
================================================================
Total params: 89,606
Trainable params: 89,606
Non-trainable params: 0
----------------------------------------------------------------
Input size (MB): 0.00
Forward/backward pass size (MB): 0.06
Params size (MB): 0.34
Estimated Total Size (MB): 0.41
----------------------------------------------------------------
```

*Fig. 11:* Neural networkconv_small_relu architecture

Similar architectures with fewer and more parameters were tested. For neural networks with about 105,000 parameters, verification for one target label takes about 20 hours (for 10 labels it takes approximately 200 hours). From this we conclude that the duration of verification increases exponentially with increasing number of parameters.

*b) Improved Work Speed*

During the analysis of the repository, the bottleneck was identified — the back_substitute function of the utils.py module, which is responsible for the integration of interval arithmetic. Profiling of this program shows that about70%of the execution time is occupied by this function (Fig. 12). The calculation graph shows similar results (Fig. 13).

| Name | Call Count | Time (ms) | Own Time (ms) ▼ |
|---|---|---|---|
| back_substitute | 24430640 | 22239630 92.9% | 17060946 71.3% |
| <method 'reduce' of 'numpy.ufunc' objec | 171164012 | 1590864 6.6% | 1590864 6.6% |
| <method 'nonzero' of 'numpy.ndarray' ol | 156399360 | 1305071 5.5% | 1305071 5.5% |
| f_wrapped | 776610376 | 6201004 25.9% | 1178936 4.9% |
| find_top_boxed_args | 776610376 | 564045 2.4% | 419477 1.8% |
| <built-in method numpy.core._multiarray | 588557196 | 4058328 17.0% | 234355 1.0% |
| roll | 47374080 | 281605 1.2% | 181411 0.8% |
| <lambda> | 1580220125 | 171697 0.7% | 171697 0.7% |
| _wrapreduction | 171162011 | 1832933 7.7% | 167766 0.7% |
| sum | 171160960 | 1999585 8.4% | 140632 0.6% |
| f_wrapped | 238679620 | 251373 1.1% | 105127 0.4% |
| delete | 27040 | 100982 0.4% | 100528 0.4% |
| array | 143931460 | 506997 2.1% | 96540 0.4% |
| apply_poly | 13520 | 11371319 47.5% | 95687 0.4% |
| <built-in method numpy.array> | 143947586 | 78817 0.3% | 78817 0.3% |
| <built-in method numpy.zeros> | 29865701 | 70790 0.3% | 70790 0.3% |
| sum | 171160960 | 2143509 9.0% | 70448 0.3% |
| <dictcomp> | 171162011 | 62815 0.3% | 62815 0.3% |
| append | 47374080 | 1042424 4.4% | 61034 0.3% |

*Fig.12:* Table of execution times of all algorithm functions

To optimize the selected bottleneck, various approaches to code optimization and library replacement were tested, as well as deployment on GPUs using the PyTorch library.

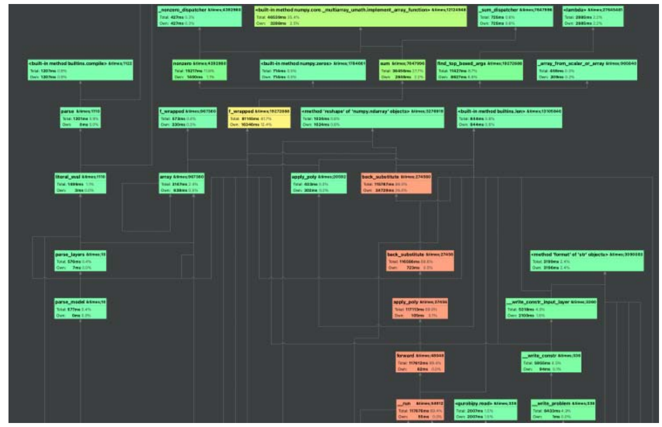

*Fig.13.* Calculation graph of all algorithm functions

It was not possible to obtain a significant increase in performance using the GPU, since the method uses a large number of not very complex calculations. As a result, calculations slowed down 10 times. This happened because GPUs are adapted for calculating large matrices, while the CPU copes better with the proposed task. The use of other libraries and code optimization led to a 20 percent improvement in the execution speed of the back_substitute function. The overall running time of the algorithm was also improved by approximately 10% (Fig. 14).

```
No backdoor
No false alarm
No stamp
Running time = 496m 6s
         4363399642 function calls (4172002925 primitive calls) in 29766.186 seconds

   Ordered by: internal time

   ncalls  tottime  percall  cumtime  percall filename:lineno(function)
 24430640 24456.822    0.001 28484.934    0.001 utils.py:147(back_substitute)

No backdoor
No false alarm
No stamp
Running time = 534m 51s
         8737689942 function calls (8591859206 primitive calls) in 32091.220 seconds

   Ordered by: internal time

   ncalls  tottime  percall  cumtime  percall filename:lineno(function)
 24430640 23547.410    0.001 29343.768    0.001 utils.py:147(back_substitute)
```

*Fig.14:* Comparison of algorithm running time before and after optimization improvements

Parallelization of the selected problem is impossible, since the newly calculated data must again be fed into the input. Nevertheless, you can try to parallelize the search for a trigger in different places, but this issue is subject to deeper study.

## IV. Practical Implementation

*a) Software and Hardware*

The main part of the described experiments was carried out on a computer complex using a central processor and having the following characteristics:

*Table I:* Hardware

| | |
|---|---|
| CPU | Apple M1 Max processor |
| RAM | 32 GB |

Experiments on the GPU were carried out using a computing cluster with the characteristics indicated in Table II.

*Table II:* Hardware, GPU cluster

| Video card | NVIDIA RTX A6000 |
|---|---|
| Processor | AMD EPYC 7532 32-Core |
| RAM | 252 GB |

Software with the characteristics shown in Table III was used.

*Table III:* Software

| OS (CPU) | MacOS Ventura 13.3.1 |
|---|---|
| OS (GPU) | Ubuntu 20.04.4 LTS |
| Python | 3.10.0 |
| numpy | 1.23.5 |
| scipy | 1.8.0 |
| autograd | 1.4 |
| | 9.5.1 |
| torchsummary | 1.5.1 |
| nvidia cuda | 11.7 |
| pytorch | 1.13.1 |

*b) Datasets and Neural Networks*

Neural networks trained on the following data sets were used:

- MNIST – a set of single-channel images of $28 \times 28$pixels. Images are divided into 10 classes — numbers from 0 to 9 (Fig. 15);
- CIFAR-10 – a set of three-channel images of $32 \times 32$pixels. Images are divided into 10 classes — airplane, car, bird, cat, deer, dog, frog, horse, ship, truck (Fig. 16).

In addition to the experiments proposed in the article, other neural networks were trained. They were analyzed using a trigger search algorithm and used to compare the original implementation and the optimized version. Neural networks that showed high accuracy on the test set, as a rule, did not have a trigger. An example of a tested neural network is shown in Fig. 11.

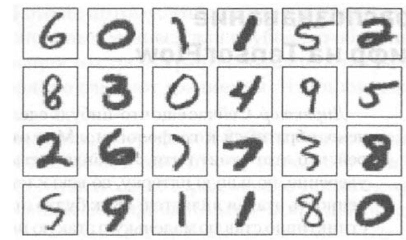

*Fig.15:* MNIST DataSet

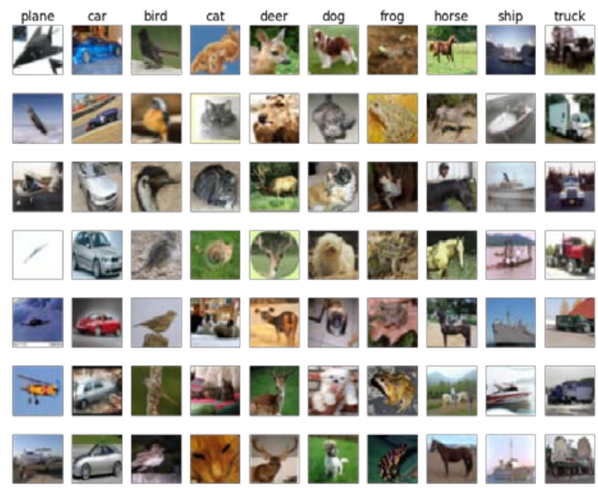


*Fig.16:* CIFAR-10 DataSet

*c) Disadvantages of the Current Implementation*

Formal verification, as a young field of science, has many difficulties with uniform standards of use. The proposed implementation of the trigger search problem has a number of significant problems that arise for the user who decides to use this algorithm. It was decided to correct the identified deficiencies as part of this work.

1. The proposed implementation works only with neural networks stored in a special format, where all weights and biases are stored in separate txt files, and the architecture itself is written in a separate spec.json file. To read neural networks in this format, a separate json_parser module is used, which extracts the weights of the neural network and prepares them for work. The inability to conduct an experiment on a neural network not described by the authors is a significant drawback;
2. The proposed algorithm works quite slowly even on small neural networks, which is natural, since formal verification very carefully analyzes the entire neural network layer by layer, neuron by neuron. Since when testing more complex neural networks with a large number of parameters, the key limitation is the running time of the algorithm, optimizing it will increase its applicability. Also, the existing implementation does not use parallelization and it was decided to fix this too;
3. The existing implementation is only suitable for testing neural networks trained on the MNIST

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dataset, and has not been adapted or tested for the CIFAR-10 dataset;

4. Support for only a limited set of layers, such as two-dimensional convolutional and fully connected layers.

In connection with the identified shortcomings, requirements were drawn up for an optimized version of the existing implementation:

1. The ability to search for triggers for ANN written in PyTorch;
2. Adding parallelization at various levels;
3. Adding support for neural networks, trained on the CIFAR-10 data set;
4. Adding support for MaxPool1D, MaxPool3D, Conv1D, Conv3D layers.

*d) GPU Usage*

As part of solving the optimization problem and using parallel computing, using profiling methods, a bottleneck was identified — the back_substitute function of the utils module (Fig. 13). Implementation of this function using the PyTorch library and graphics processing unit (GPU) did not give the expected acceleration.

This happened because the formal verification problem is poorly adaptable to GPU computing. During the calculation, there are quite a few operations that are similar to each other, and most of them depend on the previous step, which makes the use of the GPU ineffective.

It was decided to replace the used autograd library with numpy. Since the numpy library is written in C and Fortran programming languages, it is highly optimized. The autograd library is a "wrapper" of already optimized algorithms, which gives a series of small delays that accumulate and give a significant slowdown with a large number of calls. Replacing the autograd library with the numpy library increased the speed of the back_substitute function by 20 percent, and the speed of the entire algorithm by an average of 10 percent.

The table below shows the running time of the back_substitute function using various libraries. For each library, 10,000 calculations were carried out and the average value was calculated:

*Table IV:* Running time of the back_substitute function for different libraries

| Library | Back_substitute running time (s) |
|---|---|
| autograd | 0.00023 |
| PyTorch (GPU) | 0.00225 |
| numpy | 0.00018 |

*e) Using Parallel Computing*

During the study of the existing implementation of the trigger search algorithm, places were identified that could be optimized using parallelization; the pseudocode is presented in Fig. 17.

```
Algorithm 2: verifyX(N, X, (c_s, h_s, w_s), t_s)        #pragma parallel
let hasUnknown ← false;
foreach trigger position (h_p, w_p) do                  #pragma parallel
    let φ ← φ_pre;
    foreach image I ∈ X do
        let φ_I ← attackCondition(N, I, φ_pre, (c_s, h_s, w_s), (h_p, w_p), t_s);
        if φ_I is UNSAT then
            φ ← false;
            break;
        else
            φ ← φ ∧ φ_I;
    if solving φ results in SAT or UNKNOWN then
        if opTrigger(N, X, φ, (c_s, h_s, w_s), (h_p, w_p), t_s) returns a trigger then
            return UNSAFE;
        else
            hasUnknown ← true;
return hasUnknown ? UNKNOWN : SAFE;
```

*Fig. 17:* Pseudocode of the VerifyX function indicating places of parallelization

It was decided to test parallelization in two selected areas: at the stage of selecting a target label and at the stage of enumerating trigger locations. This is possible thanks to the following process. For each trigger location, a chain of conjunctions of admissible intervals of all neurons in the neural network is calculated. Since the sequence of conjunctions does not change its meaning depending on the location of the conjunction in the chain, the result when applying parallelization remains unchanged. The proposed parallelization in both cases was implemented using the standard multiprocessing library and in total gave a significant increase in speed in various experiments. On average, on the tested neural networks, an acceleration of 4 times was obtained relative to the original implementation. The results of the experiments are shown in Table V. The first half shows the results for fully connected neural networks, and the second half for convolutional ones.

Other optimizations implemented according to the formulated requirements are listed below:

1. As part of the work, a sequence of actions was implemented to convert any neural network written in PyTorch into a specialized format used by the trigger search algorithm. This pipeline has been tested for all possible types of layers and architectures, including those that were not studied in the original article;
2. To support layers of new types, the corresponding classes were implemented with processing built according to the DeepPoly formal verification method;

3. To support the CIFAR-10 data set, the images in it were normalized from 0 to 1 and converted into the appropriate specialized format. The existing implementation was adapted to use a $3 \times 3 \times 3$ trigger, and support for multi-channel triggers was added wherever this was lacking.

*Table V:* Algorithm running time before and after optimization

| Neural network | Number of parameters | Original time | Optimized time |
|---|---|---|---|
| mnist_model_0 | 79 510 | 1 223 s | 341 s |
| mnist_model_1 | 159 010 | 2 352 s | 659 s |
| mnist_model_2 | 199 310 | 6 873 s | 1 704 s |
| mnist_model_3 | 119 810 | 5 394 s | 1 328 s |
| mnist_conv_small | 89 606 | 22 452 s | 4 548 s |
| mnist_model_5 | 159 387 | 258 854 s | 74 855 s |
| mnist_conv_maxpool | 34 622 | 17 880 s | 3 632 s |
| cifar_conv_relu | 62 006 | — | 197 426 s |

*f) Assessing the complexity of the trigger search algorithm in neural networks of various architectures*

The time it takes to search for a trigger in a neural network depends on its architecture. The complexity of testing a neural network can be determined both empirically and theoretically. It will correlate with the number of parameters and depend on: the number of layers in the neural network, the size of these layers, the type of these layers. Empirically, it was found that fully connected layers are faster to check than convolutional layers. The verification time depends to a greater extent on the number of layers and to a lesser extent on their size.

The number of parameters for verifying fully connected layers can be expressed as $O(m * n)$, where m and n are the number of inputs and outputs of the layer. The number of parameters for verifying 2D layers can be expressed as $O(c * h * w)$ for Conv2D and $O(c * h^2 * w^2)$ for MaxPool2D, where $c, h$ and $w$ are the number of channels, the height and width of the kernel. Thus, it is easy to see that the more parameters the 2D layers have, the longer the neural network will take to verify.

*Table VI:* Estimation of the complexity of searching for a trigger for different types of layers

| Layer type | Complexity |
|---|---|
| Linear | $O(m * n)$ |
| Conv2D | $O(c * h * w)$ |
| MaxPool2D | $O(c * h^2 * w^2)$ |

## V. Conclusion

Formal verification algorithms are generally applicable to checking neural networks for the absence of attacks. Using the DeepPoly algorithm, you can not only check for the presence of a trigger in an image, but also generate triggers. Verification problems arise on networks containing Sigmoid and Tanh activation functions.

Probabilistic models provide a numerical assessment of testing the operation of neural networks; they can be combined with formal verification algorithms. As a continuation of the work, you can try to use other verification algorithms for these experiments, based on the analysis by zonotopes [5] of the Sigmoid and Tanh activation functions.

## References Références Referencias


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## Tips for writing a good quality Computer Science Research Paper

Techniques for writing a good quality computer science research paper:

***1. Choosing the topic:*** In most cases, the topic is selected by the interests of the author, but it can also be suggested by the guides. You can have several topics, and then judge which you are most comfortable with. This may be done by asking several questions of yourself, like "Will I be able to carry out a search in this area? Will I find all necessary resources to accomplish the search? Will I be able to find all information in this field area?" If the answer to this type of question is "yes," then you ought to choose that topic. In most cases, you may have to conduct surveys and visit several places. Also, you might have to do a lot of work to find all the rises and falls of the various data on that subject. Sometimes, detailed information plays a vital role, instead of short information. Evaluators are human: The first thing to remember is that evaluators are also human beings. They are not only meant for rejecting a paper. They are here to evaluate your paper. So present your best aspect.

***2. Think like evaluators:*** If you are in confusion or getting demotivated because your paper may not be accepted by the evaluators, then think, and try to evaluate your paper like an evaluator. Try to understand what an evaluator wants in your research paper, and you will automatically have your answer. Make blueprints of paper: The outline is the plan or framework that will help you to arrange your thoughts. It will make your paper logical. But remember that all points of your outline must be related to the topic you have chosen.

***3. Ask your guides:*** If you are having any difficulty with your research, then do not hesitate to share your difficulty with your guide (if you have one). They will surely help you out and resolve your doubts. If you can't clarify what exactly you require for your work, then ask your supervisor to help you with an alternative. He or she might also provide you with a list of essential readings.

***4. Use of computer is recommended:*** As you are doing research in the field of computer science then this point is quite obvious. Use right software: Always use good quality software packages. If you are not capable of judging good software, then you can lose the quality of your paper unknowingly. There are various programs available to help you which you can get through the internet.

***5. Use the internet for help:*** An excellent start for your paper is using Google. It is a wondrous search engine, where you can have your doubts resolved. You may also read some answers for the frequent question of how to write your research paper or find a model research paper. You can download books from the internet. If you have all the required books, place importance on reading, selecting, and analyzing the specified information. Then sketch out your research paper. Use big pictures: You may use encyclopedias like Wikipedia to get pictures with the best resolution. At Global Journals, you should strictly follow here.

***6. Bookmarks are useful:*** When you read any book or magazine, you generally use bookmarks, right? It is a good habit which helps to not lose your continuity. You should always use bookmarks while searching on the internet also, which will make your search easier.

***7. Revise what you wrote:*** When you write anything, always read it, summarize it, and then finalize it.

***8. Make every effort:*** Make every effort to mention what you are going to write in your paper. That means always have a good start. Try to mention everything in the introduction—what is the need for a particular research paper. Polish your work with good writing skills and always give an evaluator what he wants. Make backups: When you are going to do any important thing like making a research paper, you should always have backup copies of it either on your computer or on paper. This protects you from losing any portion of your important data.

***9. Produce good diagrams of your own:*** Always try to include good charts or diagrams in your paper to improve quality. Using several unnecessary diagrams will degrade the quality of your paper by creating a hodgepodge. So always try to include diagrams which were made by you to improve the readability of your paper. Use of direct quotes: When you do research relevant to literature, history, or current affairs, then use of quotes becomes essential, but if the study is relevant to science, use of quotes is not preferable.

***10.Use proper verb tense:*** Use proper verb tenses in your paper. Use past tense to present those events that have happened. Use present tense to indicate events that are going on. Use future tense to indicate events that will happen in the future. Use of wrong tenses will confuse the evaluator. Avoid sentences that are incomplete.

***11. Pick a good study spot:*** Always try to pick a spot for your research which is quiet. Not every spot is good for studying.

***12. Know what you know:*** Always try to know what you know by making objectives, otherwise you will be confused and unable to achieve your target.

***13. Use good grammar:*** Always use good grammar and words that will have a positive impact on the evaluator; use of good vocabulary does not mean using tough words which the evaluator has to find in a dictionary. Do not fragment sentences. Eliminate one-word sentences. Do not ever use a big word when a smaller one would suffice.

Verbs have to be in agreement with their subjects. In a research paper, do not start sentences with conjunctions or finish them with prepositions. When writing formally, it is advisable to never split an infinitive because someone will (wrongly) complain. Avoid clichés like a disease. Always shun irritating alliteration. Use language which is simple and straightforward. Put together a neat summary.

***14. Arrangement of information:*** Each section of the main body should start with an opening sentence, and there should be a changeover at the end of the section. Give only valid and powerful arguments for your topic. You may also maintain your arguments with records.

***15. Never start at the last minute:*** Always allow enough time for research work. Leaving everything to the last minute will degrade your paper and spoil your work.

***16. Multitasking in research is not good:*** Doing several things at the same time is a bad habit in the case of research activity. Research is an area where everything has a particular time slot. Divide your research work into parts, and do a particular part in a particular time slot.

***17. Never copy others' work:*** Never copy others' work and give it your name because if the evaluator has seen it anywhere, you will be in trouble. Take proper rest and food: No matter how many hours you spend on your research activity, if you are not taking care of your health, then all your efforts will have been in vain. For quality research, take proper rest and food.

***18. Go to seminars:*** Attend seminars if the topic is relevant to your research area. Utilize all your resources.

***19. Refresh your mind after intervals:*** Try to give your mind a rest by listening to soft music or sleeping in intervals. This will also improve your memory. Acquire colleagues: Always try to acquire colleagues. No matter how sharp you are, if you acquire colleagues, they can give you ideas which which will be helpful to your research.

***20. Think technically:*** Always think technically. If anything happens, search for its reasons, benefits, and demerits. Think and then print: When you go to print your paper, check that tables are not split, headings are not detached from their descriptions, and page sequence is maintained.

***21. Adding unnecessary information:*** Do not add unnecessary information like "I have used MS Excel to draw graphs." Irrelevant and inappropriate material is superfluous. Foreign terminology and phrases are not apropos. One should never take a broad view. Analogy is like feathers on a snake. Use words properly, regardless of how others use them. Remove quotations. Puns are for kids, not grunt readers. Never oversimplify: When adding material to your research paper, never go for oversimplification; this will definitely irritate the evaluator. Be specific. Never use rhythmic redundancies. Contractions shouldn't be used in a research paper. Comparisons are as terrible as clichés. Give up ampersands, abbreviations, and so on. Remove commas that are not necessary. Parenthetical words should be between brackets or commas. Understatement is always the best way to put forward earth-shaking thoughts. Give a detailed literary review.

***22. Report concluded results:*** Use concluded results. From raw data, filter the results, and then conclude your studies based on measurements and observations taken. An appropriate number of decimal places should be used. Parenthetical remarks are prohibited here. Proofread carefully at the final stage. At the end, give an outline to your arguments. Spot perspectives of further study of the subject. Justify your conclusion at the bottom sufficiently, which will probably include examples.

***23. Upon conclusion:*** Once you have concluded your research, the next most important step is to present your findings. Presentation is extremely important as it is the definite medium though which your research is going to be in print for the rest of the crowd. Care should be taken to categorize your thoughts well and present them in a logical and neat manner. A good quality research paper format is essential because it serves to highlight your research paper and bring to light all necessary aspects of your research.

## Informal Guidelines of Research Paper Writing

***Key points to remember:***

- Submit all work in its final form.
- Write your paper in the form which is presented in the guidelines using the template.
- Please note the criteria peer reviewers will use for grading the final paper.

**Final points:**

One purpose of organizing a research paper is to let people interpret your efforts selectively. The journal requires the following sections, submitted in the order listed, with each section starting on a new page:

*The introduction:* This will be compiled from reference matter and reflect the design processes or outline of basis that directed you to make a study. As you carry out the process of study, the method and process section will be constructed like that. The results segment will show related statistics in nearly sequential order and direct reviewers to similar intellectual paths throughout the data that you gathered to carry out your study.

**The discussion section:**

This will provide understanding of the data and projections as to the implications of the results. The use of good quality references throughout the paper will give the effort trustworthiness by representing an alertness to prior workings.

Writing a research paper is not an easy job, no matter how trouble-free the actual research or concept. Practice, excellent preparation, and controlled record-keeping are the only means to make straightforward progression.

**General style:**

Specific editorial column necessities for compliance of a manuscript will always take over from directions in these general guidelines.

**To make a paper clear:** Adhere to recommended page limits.

*Mistakes to avoid:*

- Insertion of a title at the foot of a page with subsequent text on the next page.
- Separating a table, chart, or figure—confine each to a single page.
- Submitting a manuscript with pages out of sequence.
- In every section of your document, use standard writing style, including articles ("a" and "the").
- Keep paying attention to the topic of the paper.
- Use paragraphs to split each significant point (excluding the abstract).
- Align the primary line of each section.
- Present your points in sound order.
- Use present tense to report well-accepted matters.
- Use past tense to describe specific results.
- Do not use familiar wording; don't address the reviewer directly. Don't use slang or superlatives.
- Avoid use of extra pictures—include only those figures essential to presenting results.

**Title page:**

Choose a revealing title. It should be short and include the name(s) and address(es) of all authors. It should not have acronyms or abbreviations or exceed two printed lines.

**Abstract:** This summary should be two hundred words or less. It should clearly and briefly explain the key findings reported in the manuscript and must have precise statistics. It should not have acronyms or abbreviations. It should be logical in itself. Do not cite references at this point.

An abstract is a brief, distinct paragraph summary of finished work or work in development. In a minute or less, a reviewer can be taught the foundation behind the study, common approaches to the problem, relevant results, and significant conclusions or new questions.

Write your summary when your paper is completed because how can you write the summary of anything which is not yet written? Wealth of terminology is very essential in abstract. Use comprehensive sentences, and do not sacrifice readability for brevity; you can maintain it succinctly by phrasing sentences so that they provide more than a lone rationale. The author can at this moment go straight to shortening the outcome. Sum up the study with the subsequent elements in any summary. Try to limit the initial two items to no more than one line each.

*Reason for writing the article—theory, overall issue, purpose.*

- Fundamental goal.
- To-the-point depiction of the research.
- Consequences, including definite statistics—if the consequences are quantitative in nature, account for this; results of any numerical analysis should be reported. Significant conclusions or questions that emerge from the research.

**Approach:**

- o Single section and succinct.
- o An outline of the job done is always written in past tense.
- o Concentrate on shortening results—limit background information to a verdict or two.
- o Exact spelling, clarity of sentences and phrases, and appropriate reporting of quantities (proper units, important statistics) are just as significant in an abstract as they are anywhere else.

**Introduction:**

The introduction should "introduce" the manuscript. The reviewer should be presented with sufficient background information to be capable of comprehending and calculating the purpose of your study without having to refer to other works. The basis for the study should be offered. Give the most important references, but avoid making a comprehensive appraisal of the topic. Describe the problem visibly. If the problem is not acknowledged in a logical, reasonable way, the reviewer will give no attention to your results. Speak in common terms about techniques used to explain the problem, if needed, but do not present any particulars about the protocols here.

*The following approach can create a valuable beginning:*

- Explain the value (significance) of the study.
- Defend the model—why did you employ this particular system or method? What is its compensation? Remark upon its appropriateness from an abstract point of view as well as pointing out sensible reasons for using it.
- Present a justification. State your particular theory(-ies) or aim(s), and describe the logic that led you to choose them.
- Briefly explain the study's tentative purpose and how it meets the declared objectives.

**Approach:**

Use past tense except for when referring to recognized facts. After all, the manuscript will be submitted after the entire job is done. Sort out your thoughts; manufacture one key point for every section. If you make the four points listed above, you will need at least four paragraphs. Present surrounding information only when it is necessary to support a situation. The reviewer does not desire to read everything you know about a topic. Shape the theory specifically—do not take a broad view.

As always, give awareness to spelling, simplicity, and correctness of sentences and phrases.

**Procedures (methods and materials):**

This part is supposed to be the easiest to carve if you have good skills. A soundly written procedures segment allows a capable scientist to replicate your results. Present precise information about your supplies. The suppliers and clarity of reagents can be helpful bits of information. Present methods in sequential order, but linked methodologies can be grouped as a segment. Be concise when relating the protocols. Attempt to give the least amount of information that would permit another capable scientist to replicate your outcome, but be cautious that vital information is integrated. The use of subheadings is suggested and ought to be synchronized with the results section.

When a technique is used that has been well-described in another section, mention the specific item describing the way, but draw the basic principle while stating the situation. The purpose is to show all particular resources and broad procedures so that another person may use some or all of the methods in one more study or referee the scientific value of your work. It is not to be a step-by-step report of the whole thing you did, nor is a methods section a set of orders.

**Materials:**

*Materials may be reported in part of a section or else they may be recognized along with your measures.*

**Methods:**

- Report the method and not the particulars of each process that engaged the same methodology.
- Describe the method entirely.
- To be succinct, present methods under headings dedicated to specific dealings or groups of measures.
- Simplify—detail how procedures were completed, not how they were performed on a particular day.
- If well-known procedures were used, account for the procedure by name, possibly with a reference, and that's all.

**Approach:**

It is embarrassing to use vigorous voice when documenting methods without using first person, which would focus the reviewer's interest on the researcher rather than the job. As a result, when writing up the methods, most authors use third person passive voice.

Use standard style in this and every other part of the paper—avoid familiar lists, and use full sentences.

**What to keep away from:**

- Resources and methods are not a set of information.
- Skip all descriptive information and surroundings—save it for the argument.
- Leave out information that is immaterial to a third party.

**Results:**

The principle of a results segment is to present and demonstrate your conclusion. Create this part as entirely objective details of the outcome, and save all understanding for the discussion.

The page length of this segment is set by the sum and types of data to be reported. Use statistics and tables, if suitable, to present consequences most efficiently.

You must clearly differentiate material which would usually be incorporated in a study editorial from any unprocessed data or additional appendix matter that would not be available. In fact, such matters should not be submitted at all except if requested by the instructor.

**Content:**

- Sum up your conclusions in text and demonstrate them, if suitable, with figures and tables.
- In the manuscript, explain each of your consequences, and point the reader to remarks that are most appropriate.
- Present a background, such as by describing the question that was addressed by creation of an exacting study.
- Explain results of control experiments and give remarks that are not accessible in a prescribed figure or table, if appropriate.
- Examine your data, then prepare the analyzed (transformed) data in the form of a figure (graph), table, or manuscript.

**What to stay away from:**

- Do not discuss or infer your outcome, report surrounding information, or try to explain anything.
- Do not include raw data or intermediate calculations in a research manuscript.
- Do not present similar data more than once.
- A manuscript should complement any figures or tables, not duplicate information.
- Never confuse figures with tables—there is a difference.

**Approach:**

As always, use past tense when you submit your results, and put the whole thing in a reasonable order.

Put figures and tables, appropriately numbered, in order at the end of the report.

If you desire, you may place your figures and tables properly within the text of your results section.

**Figures and tables:**

If you put figures and tables at the end of some details, make certain that they are visibly distinguished from any attached appendix materials, such as raw facts. Whatever the position, each table must be titled, numbered one after the other, and include a heading. All figures and tables must be divided from the text.

**Discussion:**

The discussion is expected to be the trickiest segment to write. A lot of papers submitted to the journal are discarded based on problems with the discussion. There is no rule for how long an argument should be.

Position your understanding of the outcome visibly to lead the reviewer through your conclusions, and then finish the paper with a summing up of the implications of the study. The purpose here is to offer an understanding of your results and support all of your conclusions, using facts from your research and generally accepted information, if suitable. The implication of results should be fully described.

Infer your data in the conversation in suitable depth. This means that when you clarify an observable fact, you must explain mechanisms that may account for the observation. If your results vary from your prospect, make clear why that may have happened. If your results agree, then explain the theory that the proof supported. It is never suitable to just state that the data approved the prospect, and let it drop at that. Make a decision as to whether each premise is supported or discarded or if you cannot make a conclusion with assurance. Do not just dismiss a study or part of a study as "uncertain."

Research papers are not acknowledged if the work is imperfect. Draw what conclusions you can based upon the results that you have, and take care of the study as a finished work.

- o You may propose future guidelines, such as how an experiment might be personalized to accomplish a new idea.
- o Give details of all of your remarks as much as possible, focusing on mechanisms.
- o Make a decision as to whether the tentative design sufficiently addressed the theory and whether or not it was correctly restricted. Try to present substitute explanations if they are sensible alternatives.
- o One piece of research will not counter an overall question, so maintain the large picture in mind. Where do you go next? The best studies unlock new avenues of study. What questions remain?
- o Recommendations for detailed papers will offer supplementary suggestions.

**Approach:**

When you refer to information, differentiate data generated by your own studies from other available information. Present work done by specific persons (including you) in past tense.

Describe generally acknowledged facts and main beliefs in present tense.

## The Administration Rules

Administration Rules to Be Strictly Followed before Submitting Your Research Paper to Global Journals Inc.

*Please read the following rules and regulations carefully before submitting your research paper to Global Journals Inc. to avoid rejection*.

*Segment draft and final research paper:* You have to strictly follow the template of a research paper, failing which your paper may get rejected. You are expected to write each part of the paper wholly on your own. The peer reviewers need to identify your own perspective of the concepts in your own terms. Please do not extract straight from any other source, and do not rephrase someone else's analysis. Do not allow anyone else to proofread your manuscript.

*Written material:* You may discuss this with your guides and key sources. Do not copy anyone else's paper, even if this is only imitation, otherwise it will be rejected on the grounds of plagiarism, which is illegal. Various methods to avoid plagiarism are strictly applied by us to every paper, and, if found guilty, you may be blacklisted, which could affect your career adversely. To guard yourself and others from possible illegal use, please do not permit anyone to use or even read your paper and file.

## Criterion for Grading a Research Paper (Compilation) by Global Journals Inc. (US)

**Please note that following table is only a Grading of "Paper Compilation" and not on "Performed/Stated Research" whose grading solely depends on Individual Assigned Peer Reviewer and Editorial Board Member. These can be available only on request and after decision of Paper. This report will be the property of Global Journals Inc. (US).**

| Topics | Grades | | |
|---|---|---|---|
| | **A-B** | **C-D** | **E-F** |
| ***Abstract*** | Clear and concise with appropriate content, Correct format. 200 words or below | Unclear summary and no specific data, Incorrect form<br><br>Above 200 words | No specific data with ambiguous information<br><br>Above 250 words |
| ***Introduction*** | Containing all background details with clear goal and appropriate details, flow specification, no grammar and spelling mistake, well organized sentence and paragraph, reference cited | Unclear and confusing data, appropriate format, grammar and spelling errors with unorganized matter | Out of place depth and content, hazy format |
| ***Methods and Procedures*** | Clear and to the point with well arranged paragraph, precision and accuracy of facts and figures, well organized subheads | Difficult to comprehend with embarrassed text, too much explanation but completed | Incorrect and unorganized structure with hazy meaning |
| ***Result*** | Well organized, Clear and specific, Correct units with precision, correct data, well structuring of paragraph, no grammar and spelling mistake | Complete and embarrassed text, difficult to comprehend | Irregular format with wrong facts and figures |
| ***Discussion*** | Well organized, meaningful specification, sound conclusion, logical and concise explanation, highly structured paragraph reference cited | Wordy, unclear conclusion, spurious | Conclusion is not cited, unorganized, difficult to comprehend |
| ***References*** | Complete and correct format, well organized | Beside the point, Incomplete | Wrong format and structuring |

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save our planet

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