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BLOCKCHAIN-BASED DEEP LEARNING FOR CANCER TUMOR DETECTION AND MONITORING

Mbarek Lahdoud[1]* and Ahmed Asimi[2]

[1,2]- Laboratory: Laboratoire des Systèmes Informatiques & Vision (LabSiv),
- Team: Sécurité, Cryptologie, Contrôle d'accès et Modélisation (SCCAM),
- Department of Mathematics-Faculty of Sciences,
- University Ibn Zohr- Agadir.

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***Corresponding Author**
Mbarek Lahdoud
- Laboratory: Laboratoire des Systèmes Informatiques & Vision (LabSiv),
- Team: Sécurité, Cryptologie, Contrôle d'accès et Modélisation (SCCAM),
- Department of Mathematics-Faculty of Sciences,
- University Ibn Zohr- Agadir

ABSTRACT

Our system aims to detect possible cancer cells, their locations and their phases after medical imaging. For this, it uses Blockchain and an artificial neural network. In our paper, we will exploit the trusted third party played by the blockchain to provide Deep Learning with a secure, reliable, unalterable and extensible data source, by browsing all the blocks and by registering new data in the case of a new object validated by Blockchain participants. These enrich the informational heritage made available to Deep Learning to learn and forge a model by adjusting the internal parameters of the neuronal network. Also, this Deep Learning can connect with other Blockchains to achieve better performance. Finally, the system composed of a blockchain and a Deep Learning user will find its application in health by a Blockchain of Health Specialists and diagnosis of diseases by Deep Learning.

KEYWORDS: Deep Learning, Techniques, Multilayer Perceptron, Blockchain, Health.

1 INTRODUCTION AND NOTATIONS

1.1 INTRODUCTION

In healthcare, finding innovative ways to improve early detection of cancer and facilitate collaboration between healthcare professionals is becoming a crucial priority. It is in this context that our innovative system emerges, combining the power of blockchain with artificial intelligence (AI) to create a revolutionary platform. Our system is based on a secure blockchain, acting as a transparent and immutable distributed network, interconnecting healthcare professionals, particularly doctors specializing in early cancer diagnosis. This blockchain technology guarantees the integrity and confidentiality of medical data while facilitating instantaneous and reliable exchange of information between stakeholders. At the same time, our system integrates advanced artificial intelligence, specifically designed for the early analysis of cancer cells. This AI leverages sophisticated algorithms and machine learning to interpret complex data from various sources, such as medical imaging scans and genetic information. The aim is to identify potential signs of cancer cell development early, thus providing doctors with valuable assistance in their diagnoses. By bringing together blockchain and AI, our system aspires to revolutionize the way doctors collaborate and diagnose cancers. It aims to speed up the diagnostic process, reduce the risk of errors and improve the care of patients suffering from this devastating disease. In short, our initiative represents a major step forward towards personalized, preventive and collaborative medicine in the fight against cancer.

In the rest of this article, we will start by providing preliminary information about the technological components of our system, namely artificial intelligence and blockchain. Then, we will give the notations used, the previous work in the field of health that makes use of the blockchain, as well as our contribution. We will also consider the evidence of security before reaching a conclusion.

Intelligence (AI) is about to invade all sectors: Health, Education, Agriculture, Social Networks, Population Monitoring and the Knowledge Economy. This discipline offers an imitation of the human brain to learn, identify complex structures in data sets as large as they are, and make decisions.[1][2] It has evolved thanks to the increase in recent years of three factors: computing power, memory space and network bandwidth. Without forgetting also, the development of its two main sub- branches which are Machine Learning (ML), Deep Learning (DL). This AI intervenes, for example in Social Networks to facilitate navigation and carry out individualized marketing and in Health to help with diagnoses and will intervene in the rest of the areas of concern, namely epidemiology and climatology.

Deep Learning:[2] which interests us in the present, is a sub-branch of ML and a set of algorithms which offers computer systems the possibility of learning through a very large number of reliable experiences relating to objects or situations in order to forge a model adapted to recognize, identify an object, in this case a cat in an image, or make a decision, for example to reduce the speed of a vehicle or even stop it to avoid a collision.

To do this, Deep Learning has relied, in recent years, on the artificial neuron (the perceptron) the basic brick, which models the biological neuron, with weighted and aggregated inputs to undergo an adequate activation function to break linearity (examples: Heaviside, Sigmoid, Tanh, ReLU) which generates a result. Deep Learning[2] is then an artificial neural network (ANN) organized in layers (MLP), see figure 1, a layer at the input, one or more intermediate or hidden layers and a layer at the output, all the neurons of the layer (N) could be connected to those of the layer (N+1), the information, which must emanate from a *secure and reliable* source, circulates through all the layers and undergoing processing there, from input to output to produce a result. Namely, each neuron receives weighted information that it aggregates, adds a bias and injects the obtained into an activation function, as shown in figure 2.

Thus, this network after the choice of its architecture can be represented by a.

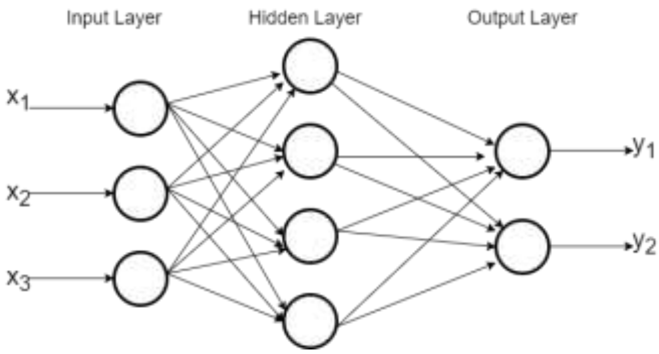

Figure 1: MLP.

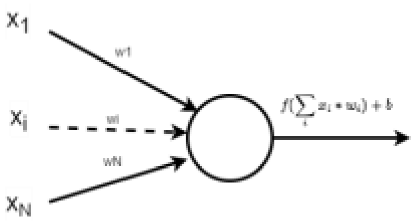

Figure 2: Perceptron.

Parametric function and our objective would be to determine the weights of the connections which minimize the error between the result calculated by the said function and the experiences read. In other words, we determine the weights that minimize the square error expressed below.

$$E = \frac{1}{2}\sum_{i}(t_i - y_i)^2 \qquad (1)$$

where *i* go through the experiences taught to the system, t_i: The true value, y_i: The calaculated value through the ANN.

Models:[3][1][6] The most frequent techniques in Deep Learning are.

- *Deep Convolutional Neural Networks(CNN)*:used mainly in processing spatial information such as image, video, speech, audio.
- *Recurrent Neural Networks (RNN)*: useful in processing time stamped data sequences such sequential data, speech, text. The difference with CNN lies in the memory of the past or future represented by a feedback loop
- *Deep Reinforcement Learning (DRL)*: concerns the autonomous driving of a car. It uses a Markov process to interact with the environment and manages states and actions.

Moreover, during training, it makes use of the backpropagation method consisting of adjusting the parameters layer by layer, from the last to the first, in the sense of minimizing the error E in the equation (1), difference between the expected result and the predicted one.

Artificial intelligence (AI)[4][5][18][19] framework refers to a structure or set of tools, libraries, standards, and conventions that provide a development framework for creating AI applications. These frameworks facilitate the process of designing, training, and deploying AI models. Here are some popular frameworks used in the AI field.

TensorFlow: Developed by Google,[4] is a widely used open source framework for developing machine learning and deep learning models. Features: Support for neural networks, symbolic and numeric operations, as well as deployments to different devices.

PyTorch: is another popular framework for developing AI applications. It is appreciated for its flexibility and ease of use. Features: Computational dynamics, ease of experimentation, and an active community.

Keras[4]: is a high-level interface written in Python that serves as an overlay to other frameworks like TensorFlow and Theano. It simplifies the creation of neural networks. Features: User-friendliness, speed in prototyping, and compatibility with multiple backends.

Blockchain: In[8], Ivan Homoliak *et al.* from the University of Technology and Design (Singapore) defined in 2019 blockchain as a data structure, representing a distributed register evolving only by adding blocks, for definition see also.[7][9] The blocks contain entries (ie transactions). The assembly and the order of the blocks are ensured by a consensus protocol[10] between the participants also called the nodes illustrated in the figure 3, Thus, trust is decentralized..

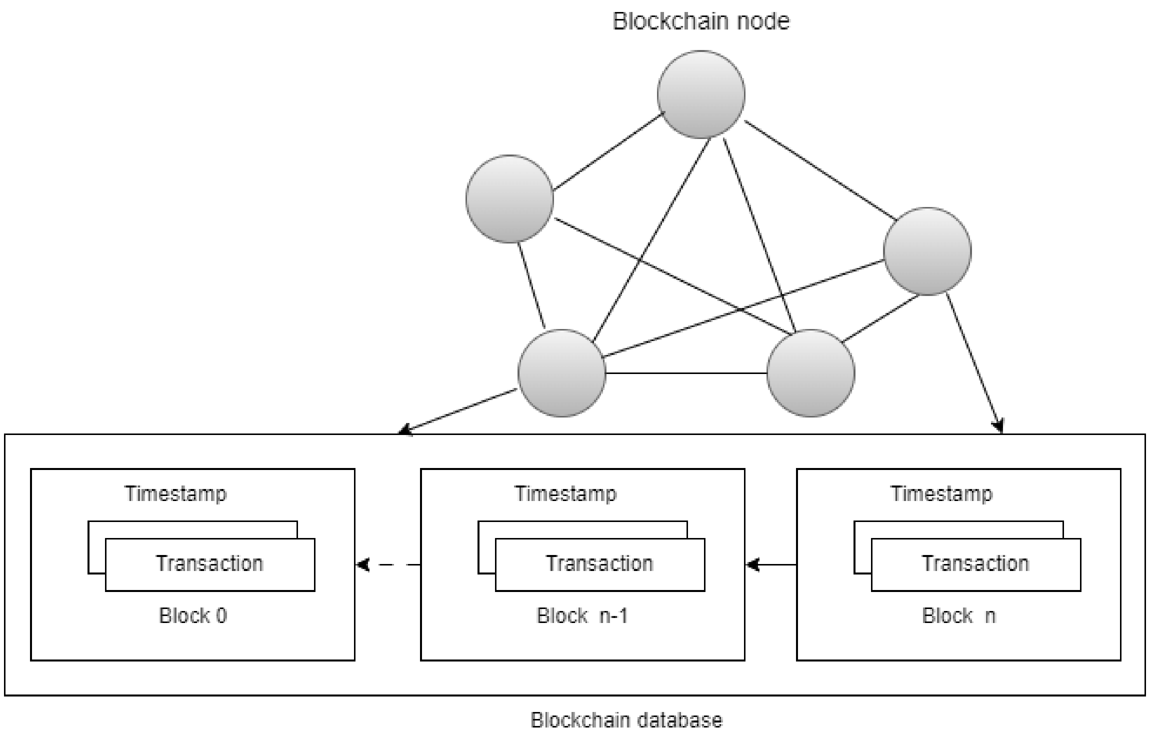

Figure 3: Blockchain network, database, blocks and transactions.

Said database is a chronological sequence of signed blocks, from the first block or the genesis block. The blockchain is in principle not modifiable by virtue of the chaining by the hashing[12][13][14] and the existence of a copy with each participant.

The three basic typologies of blockchains[11] are.

1. The private blockchain in which the consensus nodes are chosen by a specific organization (Example: Corda from New York-based startup R3 CEV).
2. The consortium blockchain first selects the nodes participating in the consen- sus; (Example: Hyperledger);
3. The public blockchain where all records are visible to all participants, and everyone can participate in the consensus; (Examples: Bitcoin, Ethereum).

recently we noticed a fourth (hybrid) that combines the elements of private and public blockchains.

Cryptography: Elliptic curves (ECC) provide a high level of security while re-quiring relatively low computational efficiency, making them particularly suitable for applications such as generating cryptographic key pairs to secure transactions on a blockchain. The mathematical properties inherent in elliptic curves make it difficult to determine the private key from the public key, thereby increasing the security of transactions. This method provides security comparable to other cryptographic approaches, but with shorter keys, thus ensuring greater efficiency in terms of calculations and required resources. In addition, it guarantees the security of communications between power-constrained devices, such as smartphones, and the blockchain.

Regarding the *Base Point*: in ECC, a base point (G) is selected on the elliptic curve, and all other points resulting from multiples of that base point (nG) are used to generate key pairs.

Each participant in ECC has a pair of keys: a private key (d) and a public key (Q). The public key is created by multiplying the private key by the base point (Q= dG).

ECC can be employed in key sharing protocols, such as the Diffie-Hellman protocol, allowing two parties to agree on a common secret key without ever directly sharing their private keys.

Additionally, ECC is used to generate digital signatures. To sign a message, the private key is used to create a signature, while the public key is used to verify the authenticity of the signature.

System (Blockchain & DL): For sensitive sectors such as Healthcare, DL requires a secure and reliable source of information to generate meaningful and relevant results. To do this, we propose to feed the DL, for its training, with data from a blockchain which is a trusted third party as indicated above. In the section 2, we will first make an overview of the related works, then our proposal will be carried by the section 3, finally the conclusion will be given in the section 5.

1.2 Notations

In this table, we will explain the notations used in our paper.

AI	:	Artificial Intelligence
ML	:	Machine Learning
DL	:	Deep Learning
ANN	:	Artificial Neuronal Network
MLP	:	Multilayer Perceptron
CNN	:	Deep Convolutional Neural Network
RNN	:	Recurrent Neural Network
$(x_i)_{i=1}^{i=n}$	:	Vector of n components
$(x_{ijk})_{i,j,k}$	:	3-dimensional matrix
$(w_i)_{i=1}^{i=n}$	:	Vector of n weights
5G	:	Fifth generation mobile networks
WHO	:	World Health Organization
GDPR	:	General Data Protection Regulation
ECC	:	Elliptical Curves Cryptography
Voxel	:	Element of a 3-D image like Pixel element of a 2-D image
CT Scan	:	A Computed Tomography scanner, a type of imaging 3-D of the inside of a body. It uses X-Ray
PET Scan	:	A Positron Emission Tomograpy, is a form of nuclear medicine imaging 3-D that shows how tissues and organs work. It uses a radioactive tracer absorded by the patient that emits γ-Ray. The tracer is collected in tumors

2 Related works

For our subject, we have gone through the available and relevant literature, we have selected to make summaries here.[15, 16, 17]

1. Following a review of the literature relating to the symbiosis between blockchain and deep learning,[15] has established a taxonomy articulated around seven (7) axes. We find this taxonomy in the figure 4.

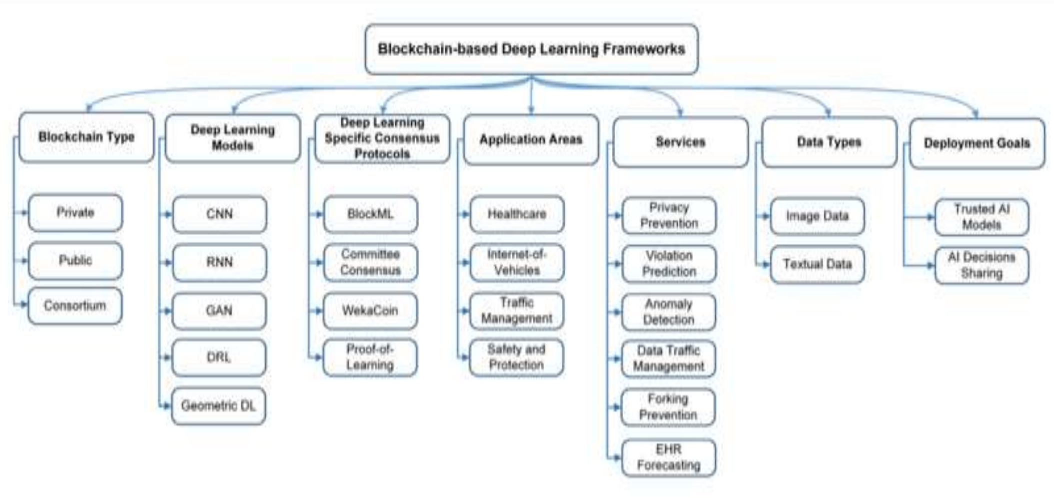

Figure 4: A taxonomy of blockchain for deep learning frameworks.

A review of Blockchain-based Deep Learning highlighted targeted areas of Healthcare, Vehicle Networks, Cellular Traffic Management, and Blockchain Protection from Adversary Attacks. A comparison of existing schemes has been drawn up.

2. The[16] has proposed a scheme for integrating blockchain and Deep Learning by reinforcement in wireless networks (beyond 5G). to share resources in a secure way and improve the performance and utility of the network. A new architecture for wireless networks, beyond 5G, secured by Blockchain and intelligent by AI has been proposed. This architecture allows secure and intelligent resource management and orchestration (spectrum sharing, etc.).
3. In[17], the diagnosis of COVID-19 by the kit and the increasing number of patients gives random results. in this sense, it has been proposed to use the integration of Blockchain and Deep Learning in Health services (example: hospitals) to access reliable data relating to the health of patients (example: Image Scanner) without invasion of their privacy. A Blockchain powered by this up- to-date data, to train a Deep Learning model that can detect COVID-19.

3 Our Contribution

Medical imaging techniques such as computed tomography (CT scan) and positron emission tomography (PET scan) are advanced tools that provide three-dimensional representations of the human body. These exams generate a set of two-dimensional images, each providing specific information crucial for medical diagnosis.

The CT scan provides a detailed view of the body’s anatomy, highlighting internal structures such as bones, organs and blood vessels. It is particularly effective in identifying structural abnormalities, including possible tumors. Images obtained from the CT scan provide precise mapping of tissues and organs, allowing healthcare professionals to detect variations in the density of the structures being examined.

On the other hand, the PET scan focuses on the metabolic aspect of the body using a different approach. The images produced by the PET scan show the metabolic activities of body tissues. This imaging modality uses a radioactive substance, usually glucose labeled with fluorine-18, which is injected into the body. Active cells, such as cancer cells that have increased metabolism, take up more of this labeled substance, resulting in bright spots in images. These spots are proportional to the intensity of metabolism at that specific location.

The integration of information from CT scan and PET scan provides a comprehensive perspective for doctors, combining detailed visualization of anatomy with specific metabolic data. This synergistic approach allows for more precise detection of abnormalities, including the localization and characterization of cancer cells. In summary, the joint use of CT scan and PET scan with specific markers offers a powerful method to diagnose and evaluate various medical conditions, with particular emphasis on early detection and characterization of tumors.

Our innovative system is based on a harmonious synergy between two cutting- edge technologies: Blockchain and Deep Learning, detailed in figure 5. By implementing these two emerging technological pillars, our revolutionary approach is dedicated to improving medical diagnostics, particularly in the healthcare field. In particular, our system uses 3D images, combining anatomical and metabolic data, to detect cancerous tumors early.

The integration of Blockchain into our system guarantees increased security and transparency in the management of medical data. This distributed ledger technology ensures immutability of information, preventing unauthorized alteration of sensitive medical data. This preserves patient confidentiality while providing healthcare professionals with secure access to crucial information for diagnosis and treatment.

On the other hand, Deep Learning, a branch of artificial intelligence, powers our system with advanced analysis capabilities. Using complex algorithms and deep neural networks, our system is able to extract meaningful information from 3D images, enabling early detection of cancerous tumors. This revolutionary approach continually adapts and learns, improving its accuracy over time.

Using 3D anatomical and metabolic images, our system provides a holistic understanding of medical conditions, enabling early detection of cancerous tumors. This early diagnosis paves the way for more effective treatments and increased chances of recovery. Ultimately, our initiative aims to transform the way health is approached by combining technological innovation, data security and improved medical care, placing our system at the forefront of contemporary medical advances.

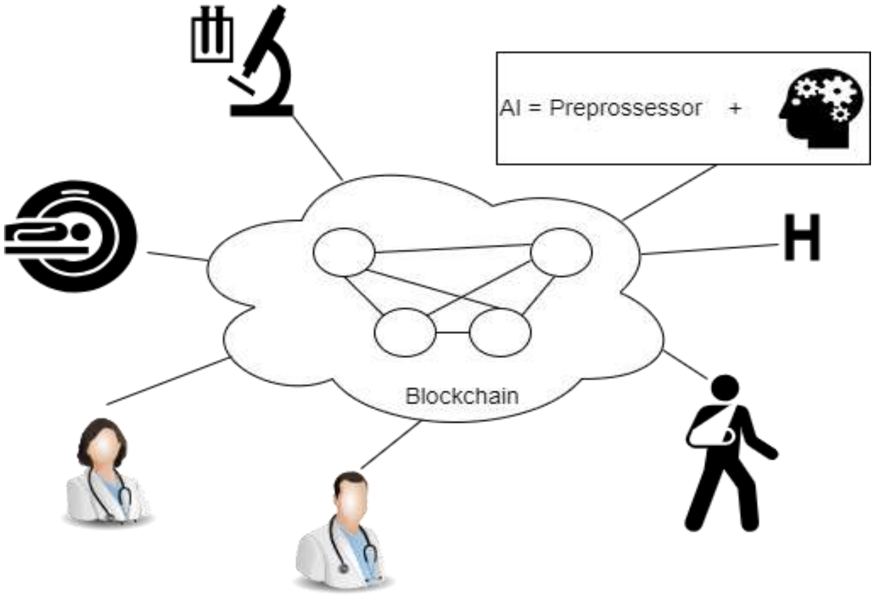

Figure 5: Our system composed of a Blockchain network and AI.

The chosen blockchain takes a hybrid approach, respecting GDPR and connecting doctors as validators. In addition, this variant of Blockchain stands out for its exceptional speed in reaching consensus and adding blocks to the ledger.

Stakeholders include artificial intelligence entities, hospitals, laboratories, radiologists, as well as doctors forming the blockchain validation team. Initial access to the blockchain is subject to the signing of a charter specifying, among other things, the consensual mode of the blockchain and the management of absences of attending physicians. If cancer cells are detected, doctors make a diagnosis and refer the patient to the appropriate department for a treatment protocol.

Transactions, including prescriptions, images (CT Scan or PET Scan), and test results, are authenticated by their issuers. This data is examined and validated by the participating doctors of the blockchain for updating it. It is important to emphasize that the blockchain is immutable, containing reliable data, and that participants are only identifiable by their address (the hash of their cryptographic public key). Consensus within the blockchain is reached by a majority opinion approved by the attending physician.

Data. The information circulating in the Blockchain is transactions or blocks: Transactions are prescriptions, x-ray images or biological analysis.

Blocks are of six types.

1. Patient's medical form. it contains past or current illnesses, medications cur- rently in use, hereditary illnesses,...
2. CT Scan Images: from a CT scanner for producing a X-Ray Image.
3. PET Scan Images: from a PET scanner for producing a γ-Ray Image.
4. Test results: from an analysis (example, biopsy).
5. Medical Report to indicate either the detection of cancer cells, their stages and their locations either negative.
6. Prescription containing Doctor Directions.

So the block, see the figure 6, has the following structure:

i)- A header containing metadata.

ii)- A body contains all the information relating to the operation.

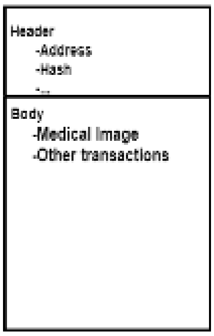

Figure 6: Block Structure.

Header

- N BC: Block number in the blockchain;
- N PA: Block number in the patient's history;
- N PB: Patient number;
- Kp: Patient Public Key;
- Hprevious: Hash of previous block;
- Hpresent: Hash of the body of the present block;
- Hpatient: Hash of previous bloc in the patient's history;
- Tbloc: Type of the bloc;
- PAT NAME: Names of Patient, which can be encrypted by the treating doctor's public key;
- DR NAME: Identity of the Doctor Responsible for the operation;

- Signt: Signature of the issuer.

Body

V IND: Vital Signs (body temperature; heart rate (the rate of your heartbeat); respiratory rate (rate of breathing); blood pressure; oxygen saturation (the amount of oxygen circulating in your blood));

- TEST RES: Test Results (Blood glucose, Biopsy).
- IMG CT: Image CT Scan;
- IMM PET: Image PET Scan;
- M REPORT: Medical Report;
- PRESC: Prescription.

Diagram

We assume that the patient is cared for by a doctor participating in the blockchain. This doctor has a patient file including personal data, public keys, as well as the content of the "Patient Medical File" block. To obtain a diagnosis, we will follow the phases below, illustrated in the diagram in figure 7.

Phases

1. Registration/Login
2. If the patient does not have an account, he creates one, thus generating two cryptographic keys: a public key and a private key.
3. Otherwise, he connects to interact with the blockchain in general and, more specifically, with his treating physician in order to request a preventive cancer diagnosis.
4. The attending physician sends, via the blockchain, a prescription for a scan.
5. The CT image is broadcast by the radiologist on the blockchain.
6. If the doctors' analysis detects cancer cells, the patient is advised to follow a treatment protocol.
7. Otherwise, a prescription is issued for a PET radio scan, providing information on metabolism.
8. The PET image is broadcast by the radiologist on the blockchain.
9. If the doctors' assessment reveals the presence of cancer cells, the patient is encouraged to follow a treatment protocol.
10. Otherwise, a negative result is broadcast on the blockchain.

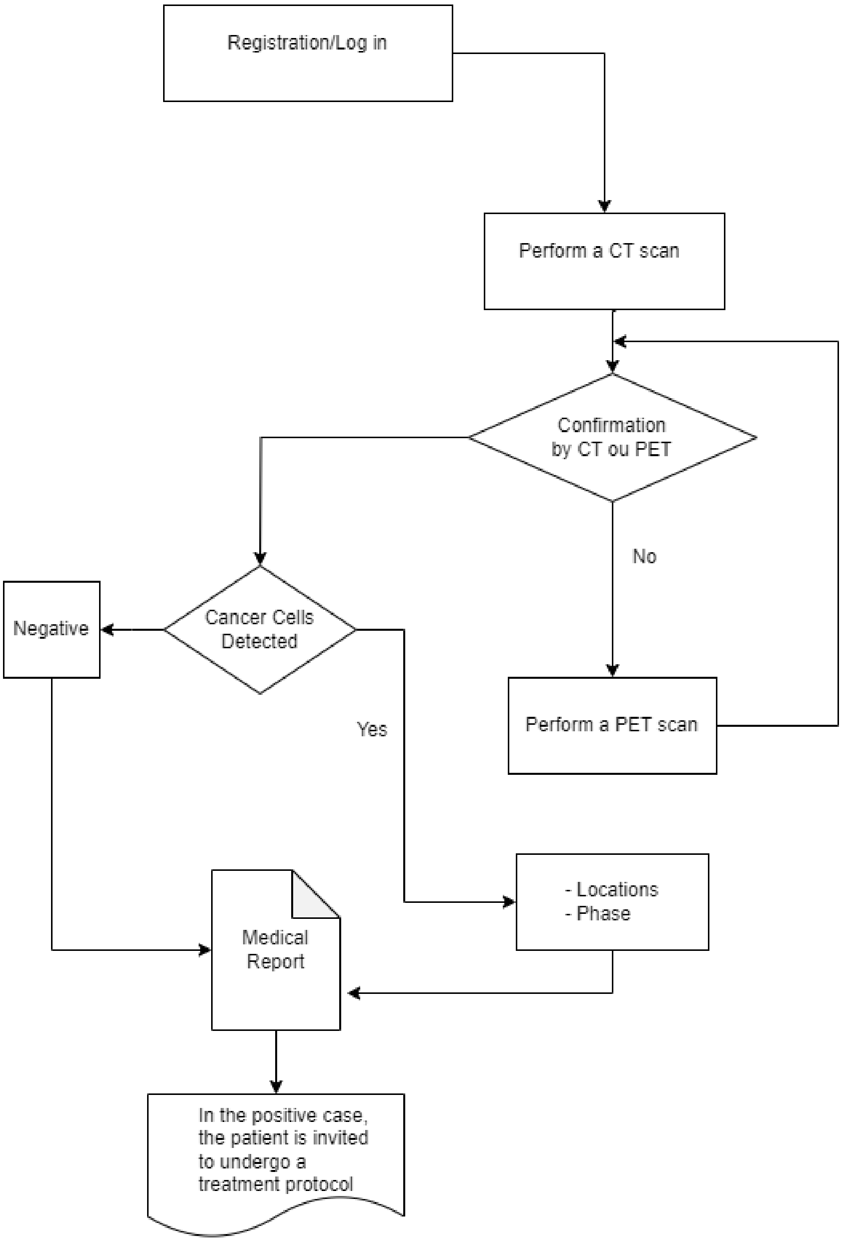

Figure 7: Consultation diagram.

Furthermore, a AI Entity, composed of preprocessor and ANN, trained on a hug number of reliable experiences stored in certfied databases (dataset). This model updates from the blockchain, then detects or predicts for each new input. If the result is validated by the Participant Doctors, it will be added to the Blockchain. The Blockchain/AI Entity is mature when almost all of the AI propositions are approved by the Doctors. Also, this AI entity, in the event of detection of cancer, calculates and gives the total volume of tumors.

The medical image, resulting from a scanner, is a matrix $(x_{ijk})_{i,j,k}$ of voxels (or a series of 2D-images $(x_{ij})_k$) which we take as input our ANN, to detect possible irregularities in the cellular tissue, according to four (4) class labels namely: 1: Negative, no tumor detected; 2: Tumor, at the beginning; 3: Tumor+, 4: Metastasis: tumors on different tissues

- **Negative**: No tumor.
- **Tumor**: Early tumor with lesions. See figure 8.

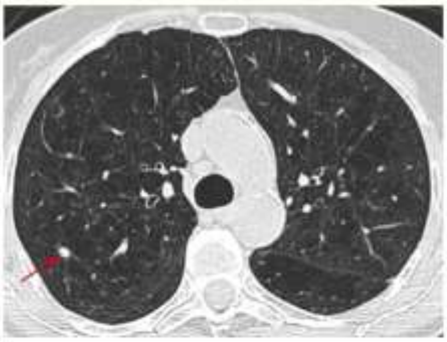

Figure 8: Solid Cancer.

- **Tumor plus**: Malignant tumor with extensions. See figure 9.

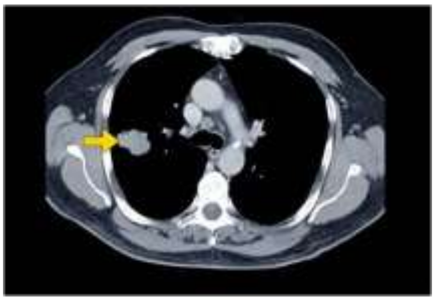

Figure 9: Solid Cancer In Extensions.

- **Metastasis**; Malignant tumors on two organs. See figure 10.

Figure 10: Solid Cancer on two organs.

Hence we will have four(4) levels associated with each organ as ANN output.

4 Proof of Security

Our Blockchain, a ledger duplicated between participants, is inherently designed to be unalterable. Additionally, its blocks are interconnected, with each block enclosing the hash of the previous one, thus significantly increasing resistance to modification. This chain structure ensures increased system integrity, as any alteration of one block would affect the entire chain, making changes extremely difficult.

Additionally, each Blockchain participant is provided with two distinct keys: a public key, which is used to generate its address and encrypt messages intended for it, and a private key, used to decrypt, sign and guarantee the authenticity of transactions. This double authentication strengthens the security and identity of actors within the Blockchain.

The transactions housed in the body of the block are represented by the Merkel root, which is inserted in the block header. This Merkel root is obtained by a pairwise hashing process of transactions, and it constitutes the reference point which guaran- tees the integrity of the data within the block. Thus, any alteration of transactions would be immediately detected, strengthening the reliability of the system and the confidence of participants."

5 CONCLUSION

The Deep Learning sub-branch in the field of Artificial Intelligence (AI) plays a crucial role in transforming sectors by investing in innovative technologies such as blockchain. This convergence promises to provide reliable and secure solutions while offering the possibility of assisting or replacing traditional specialists.

The origin of decisions, now anchored in the alliance of Deep Learning and blockchain, ensures unprecedented transparency and traceability. The information stored in a decentralized manner in the blockchain contributes to the reliability of the data, thus eliminating the risks of manipulation and falsification.

The observed growth in computer power, with an expected acceleration thanks to quantum computers, promises to significantly improve reliable learning orchestrated by Deep Learning and Blockchain. This evolution will result in more relevant and real-time decisions, thereby boosting operational efficiency across various sectors.

This technological synergy also extends to projection into the metaverses, where advances in Deep Learning and blockchain will create more interactive, realistic and functional virtual environments. Unresolved problems in various areas will thus be able to find innovative solutions, propelling society towards new technological and economic horizons.

In summary, the evolution of bandwidth, the growth of computing capabilities, in particular with the advent of quantum computers, combined with the integration of Deep Learning and blockchain, are paving the way for a technological revolution that transcends boundaries of traditional sectors. This convergence promises to bring more informed decisions, innovative solutions and a profound transformation of the metaverses, marking a significant step in the progress of Artificial Intelligence and Blockchain.

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