AI Diagnosis White Paper

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Abstract

Today, the medical industry is undergoing significant changes through technological advancements. These changes are being driven by a new technology, artificial intelligence (AI). The term, ‘artificial intelligence’ is used when an intelligent machine is capable of mimicking cognitive functions similar to that of humans such as reasoning, perception, and learning. However, there are a number of obstacles in the implementation of this technology, such as the transparency and interpretability of algorithms. These are considered major issues in the field of AI, especially since many applications of AI affect human lives both directly and indirectly. Other obstacles that interfere with the advancement of AI are the difficulty to obtain talent, the lack of access to vast datasets, and the lack of quality labeled data.

The Circuli Team introduces a unique blockchain structure architected for decentralized medical diagnosis development. The Circuli platform improves the environment for medical institutions, healthcare professionals, research labs, and commercial and private entities to advance medical diagnosis. The blockchain will allow for extensive accessibility of advanced medical technology anywhere in the world and the Circuli Team believes that many can benefit. Blockchain technology will allow for secure and transparent exchange of information between users and decentralization will lead to a community owned platform where all contributors will be at the heart of the product.

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1. Introduction

The healthcare industry has been undergoing significant changes in recent times with the integration of advanced technologies, such as artificial intelligence (AI), and the slow shift from a centralized system to a more decentralized system. The goal of the Circuli Team is to revolutionize the emerging field of AI by decentralizing medical AI diagnosis, provide an ecosystem for the development of AI diagnosis research, and use blockchain technology to give access to transparent and secure transactions. AI diagnostic algorithms must be transparent and interpretable because not only is it important to have an accurate diagnosis, but to understand the process of coming to that decision and placing trust in the results. The Circuli platform will facilitate development of new AI diagnostic models by integrating medical data providers and professional medical data labelers into the community. In other words, the Circuli platform will provide access, tradability, and empowerment by creating a viable hub for: medical institutions, medical researchers, AI developers, patients, and commercial, public and private entities.

Through the Circuli platform, users will be able to create projects with the goal of providing medical AI diagnostic solutions. The ecosystem is built for AI scientists, data providers and data labelers, who will all contribute in the development of an algorithm by supplying the necessary data for training it. Circuli will promote contribution through incentives and rewards for all participants. Circuli will be used to facilitate the development of AI diagnostic algorithms and it can be applied to automated medical diagnosis to aid health professionals, in applications regarding medical image classification, segmentation, and object detection tasks. AI diagnostic algorithms will further help provide access to a means of affordable diagnosis and analysis in medical systems. Therefore, the Circuli team would like to encourage each project to open their algorithms to the public.

2. Problems

2.1 Preliminary Diagnosis

Preliminary diagnosis is the diagnosis that a health professional makes based on early study and analysis of a patient's condition, before the completion of specialized or more definitive studies. Primary care is the first point of contact to healthcare for most people and they may receive preliminary diagnosis during the process. Primary care is crucial for two reasons: first, it prevents the ongoing condition or disease from developing; and second, it prevents disease outbreaks by finding and restraining patients with contagious diseases. However, preliminary diagnosis has been facing challenges due to a global physician shortage, and the high investment of cost and time when visiting a physician.

2.1.1 Physician Supply Shortage

The World Health Organization (WHO) forecasted that the world will have a shortage of 12.9 million healthcare workers, which includes doctors, midwives, nurses, and other health workers, by the year 2035. In 2013, that figure was at 7.2 million[1]. This number indicates the insufficient number of health professionals in many countries as well as the amount of people who are unable to receive appropriate care. Some reasons for this shortage is that not enough people are entering the profession, while the aging healthcare workers are retiring or leaving to pursue other work options. Moreover, many of the new healthcare workers are not being adequately trained. According to a study released by the Association of American Medical Colleges, the United States will have a shortage of between 7,300 and 43,100 primary care doctors by 2030[2]; the 25th and 75th percentile were taken into account to exclude extreme cases.

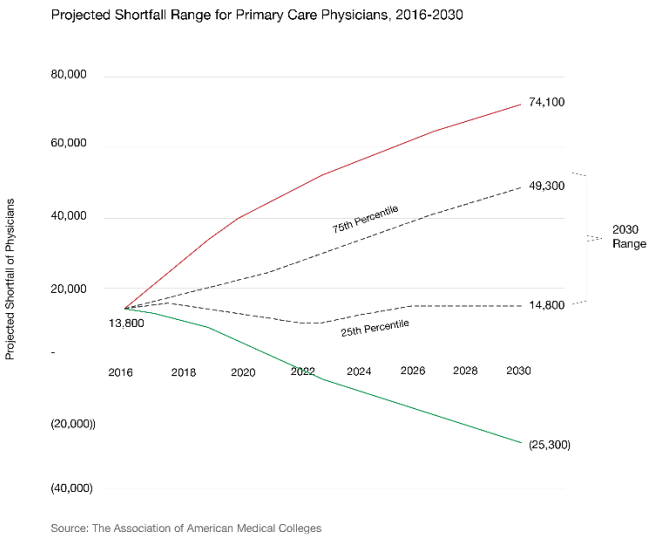

Figure 1: Projected Shortfall Range for Primary Care Physicians

The global shortage of healthcare workers is a concern because the demand for healthcare is growing. The demand is growing along with the continuing growth of human population, especially those over the age 65 to 75, which is projected to increase by 55% and 73%, respectively, by 2030. In addition, it has been found that the ratio of healthcare workers to the local population is directly related to the survival of women during childbirth and the infant mortality rate. In 2012, most of the 6.6 million deaths of children under 5 years old resulted from treatable and preventable diseases[3]. It is concluded that as the number of health workers decline, the survival rate of women and infants declines proportionately.

Due to the rising demand for healthcare and decreasing amount of health workers, more people are seeking primary care through less traditional methods such as telemedicine, medical tourism, and medical AI diagnosis.

2.1.2 Cost and Time

Preliminary diagnosis should be easily accessed by those who need it, yet long wait times and high costs are discouraging people to go to the hospital to receive primary care. A study published by the American Journal of Managed Care concluded that the average time of a doctor's visit was, in total, 121 minutes; 37 minutes of travel, 64 minutes of waiting, completing paperwork, and billing, with only 20 minutes of face-to-face meeting with a physician[4]. The average price of an uninsured patient appointment in the United States was quoted as $200, according to a research conducted in 2013[5]. Even with improvements in the healthcare system, the time and cost involved often discourages people from visiting health professionals.

2.2 Artificial Intelligence in Healthcare

In recent years, there has been a significant progress and impact of AI in healthcare. The AI market in healthcare is growing at a fast rate and is estimated to be worth $10 billion by 2025[6]. This market clearly shows potential of growth and can bring a significant change in the healthcare industry and improve society as a whole. Yet, it still faces multiple challenges that will have to be overcome before its full potential can be achieved.

2.2.1 AI Datasets

When using AI technology, being able to attain an adequate amount of reliable data is just as, or sometimes even more, important as developing an algorithm. Google and other major technology companies have been known to share research findings and codes with the world; hence, it provides a guide for other companies when they try to create and apply neural networks into their own services. Unfortunately, although many companies have the tools and knowledge

to build neural networks, they lack the sufficient amount of data required to train it, which could lead to overfitting.

Another major problem with data for medical AI is the accuracy of data labels. In order to effectively train neural networks, correct data labels by professionals are required. When medical data brokers get data from hard copies, whether document or photo, and transfer it to a computer, the data often undergoes text corruption. This could lead to the AI learning incorrect patterns or other forms of error, hence becoming useless. Many companies also have a limited number of data labelers, meaning that they would typically not verify the labels. This also leaves room for errors when training AI models.

2.3 Regulation and Compliance

The inception of the Internet has allowed for the world to be more connected than ever before. It allows people to instantaneously share ideas, knowledge, and skills with any other person that is connected. The Internet has been able to create a space for solely online-based communities and has even led some sociologists to acknowledge a new field of study called, 'digital sociology'[7]. At the end of 2017, the global penetration rate of the Internet was about 54.4%, or 4.1 billion users[8], with a growth rate of 1052% from the year 2000. Currently in the United States, about nine out of ten adults use the Internet[9]; comparably, a 2016 statistic survey showed that in Europe, almost eight out of ten used the Internet on a regular basis[10]. This growth and adoption has been beneficial for the development of many technologies, such as AI, but has also led to complications in terms of trust between users. The easily shareable and ubiquitous nature of the Internet has motivated countries to adopt laws in order to protect an individual's digital information and data.

2.3.1 United States HIPAA

The United States Department of Health and Human Services (HHS) has adopted a legislation, called the Health Insurance Portability and Accountability Act of 1996 (HIPAA). This legislation provides data privacy and security provisions, also known as HIPAA Privacy Rule, for safeguarding an individual's electronic protected health information (ePHI). HIPAA requires Covered Entities (health plans, health care clearinghouses, and health care providers who transit any patient information electronically) and Business Associates (anyone who deals with protected patient data for 'Covered Entities') to be compliant with the guidelines that they have put forth. Any third-party entity is legally bound to the HIPAA Privacy Rule when entering a Business Associate Agreement (BAA) with a Covered Entity, after which they become a 'Business Associate'. These rules are enforced by the Office of the National Coordinator (ONC) for Health Information Technology of the HHS.

2.3.1.1 Violations

The HIPAA Privacy Rule is not just written as a suggestion, but as the guidelines enforced by the OCR. If the OCR determines that privacy laws were violated, a fine is imposed upon the Covered Entity, depending on the severity of the violation.

In 2016, Memorial Healthcare System (MHS) paid $5.5 million USD to settle their potential violations of HIPAA Privacy Rule[11]. This settlement was based on the violation of audit logs and permissions. Specifically, the login credentials of a former employee of an affiliated physician's office had been used to access the ePHI maintained by MHS's system. MHS had protocols and procedures in accordance with the HIPAA Privacy Rule, but they failed to implement these procedures, which consequently, led to their settlement. In addition to the fines, the OCR required the Covered Entity, MHS, to write out corrective action plans in response to the violation.

Fines and violations are not only imposed on Covered Entities, but also on Business Associates, as was the case with Catholic Health Care Services of Archdiocese of Philadelphia (CHCS). CHCS was a Business Associate that provided management and IT services to six nursing facilities, the Covered Entities. The theft of a CHCS-issued iPhone, which was unencrypted and not password protected, led to a fine of $650,000. The iPhone, with its lack of password protection and encryption, easily exposed detailed patient ePHI, such as social security numbers, diagnosis information, medical procedures, and the names of family members. Again, the OCR and the CHSC agreed to a corrective action plan to prevent future data breaches[12].

Another kind of violation would be the failure of a Covered Entity to enter into a BAA with a company that the HIPAA Privacy Rule would define as a Business Associate. Raleigh Orthopaedic Clinic was fined $750,000 for a violation in 2013[13]. Raleigh Orthopaedic Clinic provided X-ray films and related ePHI to a third party vendor to convert and transfer the images into electronic form. The vendor, acting as a Business Associate, did not enter into a BAA with Raleigh Orthopaedic Clinic; therefore the vendor never officially provided the clinic with assurances of the protection of the provided ePHI.

2.3.2 EU GDPR

Starting from May 25, 2018 the European Union adopted a framework for data protection called the General Data Protection Regulation (GDPR). The GDPR is a legal framework designed to protect the data of EU citizens by giving them more control over their personal data. The GDPR does this by defining and giving guidelines to how organizations, private and public entities, or the government should handle personal information to ensure healthcare data is not susceptible to attacks, breaches, or to be misused. Furthermore, the GDPR applies to any organization that offers services to citizens or residents in the EU; this means that it also applies to organizations that are located outside the EU[47].

2.3.2.1 Penalties

Compared with the “Data Protection Act”, the new GDPR has undergone many changes. For example, to process large amounts of data health organizations need to appoint a data protection officer (DPO) and a “data protection impact assessments” (DPIAs) is required. In addition, organizations were under no obligation to report data breaches to anyone, but now, the organization must report the breach within 72 hours to a data protection regulator and those affected by the breach[49].

Failure to comply with the GDPR guidelines can lead to penalties of up to $24.8 million or 4% of the global annual turnover of the business, whichever is higher[48]. These penalties do not only apply to organizations within EU countries, but also affects any entity that deals with European citizens’ data whether their facility is physically in the EU or not.

3. Current State of AI and Healthcare

In viewing current medical market trends, artificial intelligence is becoming increasingly integrated with preliminary diagnostics and medical imaging diagnostics. This technological advancement in the medical market potentially expedites the decision-making process and increases the accuracy of diagnostics, along with treatment planning that follows. Constant technological progress in the diagnostics field has increased the demand for remote diagnostic imaging technologies and devices, which has driven growth of the medical market as a whole. The global diagnostics market, especially the primary care point-of-care (POC) diagnostics market, is forecasted to be worth about $8.6 billion in 2025, with a CAGR of 3.5% from 2018 to 2025[14]. With the rapid development of artificial intelligence and its continued integration with diagnostics technology, the global medical diagnostics imaging market will grow considerably.

3.1 Medical/Diagnostics Imaging

The rising prevalence of chronic diseases, technological advancements, and the demand for better quality medical care are driving the growth of the global healthcare industry. Of the healthcare industry, the medical imaging devices, medical imaging software, and medical diagnostic software market are all growing rapidly. Advanced medical software is one of the biggest recent changes in healthcare, as more people have the desire to connect devices together for improved control, monitoring, and reporting, as well as having increased safety and security.

The global market size for medical imaging devices has increased rapidly over the recent years and will continue to do so. As shown in Figure 2, the market is expected to generate a revenue of $46.6 billion by 2023 with a CAGR of 5.47% from 2017 to 2023[15]. Within the medical imaging devices market, the medical diagnostic imaging solutions market is growing at a faster rate than imaging devices.

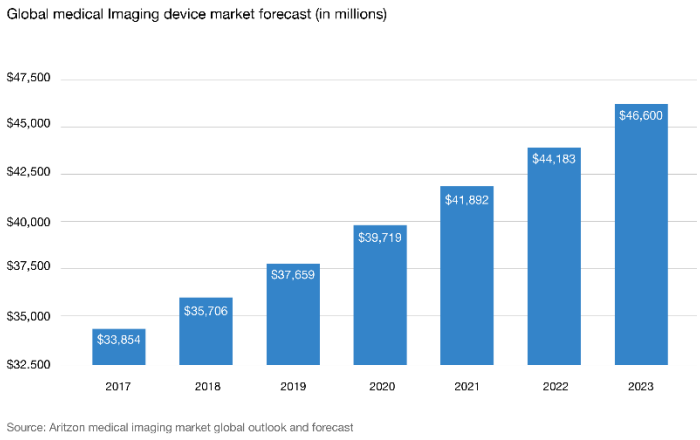

Figure 2: Global medical imaging device market forecast

The global medical imaging analysis software market is also growing globally with the increased need for a consistent software solution. The global medical imaging software market was valued at $2.46 billion in 2017 and is expected to reach a value of $4.1 billion by 2023, at a CAGR of 8.9% over the forecast period[16]. North America is expected to account for the biggest share of the medical imaging analysis software market; in 2017, it was worth $893.5 million[17]. The North American market growth is attributed to factors such as growing geriatric population, ongoing research, and fast adoption of technologically advanced imaging systems. Europe is expected to hold the second largest share, while Asia Pacific is projected to expand at an above average CAGR of 9.5% during this period[17]. The medical imaging analysis software market also reflects medical imaging diagnostics software. With the recent advancement of technology, especially regarding AI technology, more companies are supplying applications of computer-aided diagnosis.

The medical/diagnostics imaging market was valued at $33.7 billion in 2016 and is expected to grow at a CAGR of 5.7% until 2025[18]. The main factors of growth of the medical diagnostic imaging services market are similar to the United States' medical imaging analysis software market; increasing geriatric population, rising awareness for early diagnosis, technological advancement, and increased government funding[19]. Currently, the United States' medical imaging market share is the largest, owing to its willingness to adopt advanced healthcare technologies like medical machine learning diagnostic imaging solutions. Its top device vendors are GE Healthcare, Siemens Healthcare, Philips Healthcare, and Toshiba Medical[20]. The Asia Pacific region accounted for about one-third of the market share in 2015 and is expected to continue growing at the fastest rate due to its aging population[21].

3.2 Artificial Intelligence

The use of AI in the healthcare industry has been on the rise because of its ability to collect and analyze a profusion of data with speed and accuracy. Machine learning techniques have been applied to several areas in medicine, such as diagnostic imaging, genomic analysis, electrodiagnosis, etc. As seen in Figure 3, a substantial proportion of the AI literature analyses data has been focusing on diagnostic imaging due to its vast amount of data and real-life use cases. Some AI diagnosis cases have already proved to improve diagnostic accuracy of CT scans, MRI scans, and Picture Archiving and Communication Systems (PACS) by 91%[22]. For example, the model developed by Hope, Seghier, Leff, et al., can predict the outcome and recovery after stroke with lesions from MRI images[23].

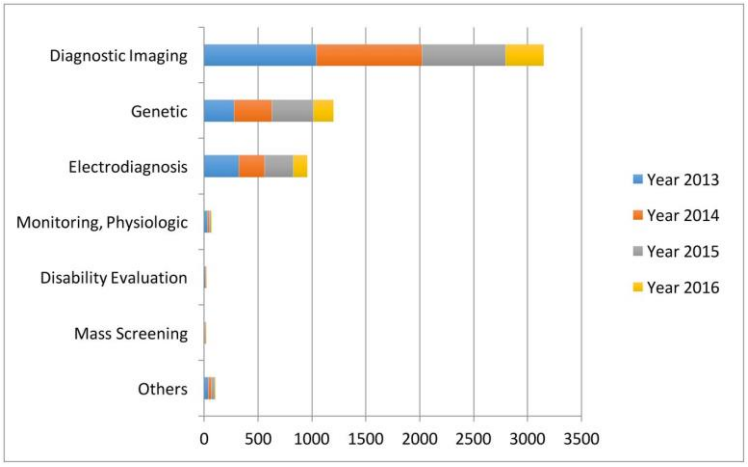

Figure 3: AI literature analyses from the PubMed database

3.2.1 Transparency and Interpretability

As much as AI is becoming more integrated into our everyday lives, such as through mobile applications, medical diagnosis, and the automotive industry, it is important to ensure that the AI technology used is beneficial, safe, fair, and morally sound. New regulations and safety measures are currently being created in order to define the legal boundaries and status of AI technologies. As Microsoft Corporation put it, training AI to remove bias or other errors is 'critical if we are going to deploy machine learning in applications that affect people's health, welfare, and social opportunities[24].

Several organizations and institutions are proposing guidelines and principles for AI technologies. Some examples are the UNI Global Union Reflection on the Future of Work[25], and the European Economic and Social Committee (EESC) Opinion: Artificial Intelligence[26]. These guidelines are set in order to ensure the responsible development and use of AI with human values and moral philosophies. The three pillars of ethical AI technology can be viewed as transparency, accountability and responsibility.

More companies like Microsoft are developing AI technologies for healthcare. Microsoft has applied transparent learning to problems in healthcare such as diabetes, pneumonia, and 30-day readmission risk prediction. They focus on not only training a model with high-quality data, but also repairing and fixing models when there is an issue. Furthermore, Microsoft's AI technology development approaches important social problems such as recidivism prediction and credit scoring, where bias based on race, gender and nationality are important issues to take into account[24].

3.2.2 Artificial Intelligence Healthcare Market

The ever increasing volume of big data, especially for medical data, is driving the AI market and the use of cloud computing software. The global AI healthcare market was worth about $714 million in 2016 and is expected to grow to more than $10 billion with a CAGR of 35.5% by 2025[6].

The United States' AI healthcare market was valued at $320 million and Europe's market size was valued at a $270 million in 2016[27]. Due to the potential of AI healthcare, multi-billion corporations such as IBM, Google Inc., Nvidia, and Microsoft, are investing in the development AI in healthcare.

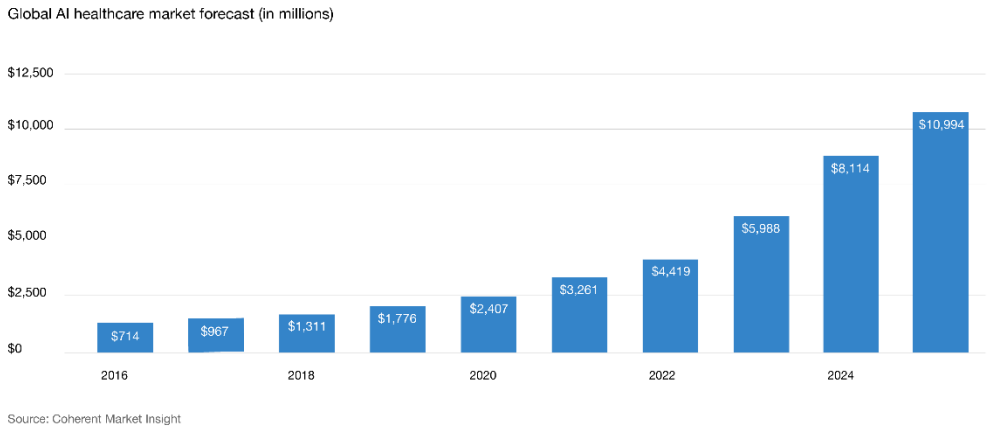

Figure 4: Global AI healthcare market forecast

3.2.3 AI Diagnosis Use Cases

The FDA is currently constructing a regulatory framework regarding AI software medical devices. About 75% of Class II (FDA classification) devices require some form of clinical trials to demonstrate safety and efficacy. In April 2018, the FDA permitted marketing of IDx-DR, an AI-based diagnostic system, created by IDx-LLC, used for detection of mild level eye disease diabetic retinopathy. In a clinical trial, the device was able to correctly identify the presence of more than mild diabetic retinopathy 87.4% of the time, while it could identify those who did not, 89.5% of the time[28].

The FDA also approved the first machine learning application for healthcare, Arterys, a cloud-based medical AI imaging platform. Arterys uses a deep learning algorithm to aid radiologists in analyzing MRI images of the heart, lung, and liver. With the continuation of the FDA approval for AI software and further development of AI technology for healthcare, the market is expected to grow significantly in the coming years.

Zebra Medical Vision, Ltd. is one of many companies that is shifting to cloud-based software with its medical image analytics platform. Zebra uses deep learning imaging analytics that is capable of detecting intracranial hemorrhages and lung and liver disease. Their platform provides imaging research solutions for clinicians along with advanced learning and computer vision diagnostic algorithms for developers. Zebra's AI1 "All-In-One" imaging analytics package has already analyzed more than 1 million scans in over 5 countries[29]. Zebra has been granted CE regulatory approval, but has yet to receive FDA clearance.

3.3 Regulation in the United States

In the United States, the Department of Health and Human Services (HHS) has been ardently advocating the importance of security in electronic health data. In 2009, the Health Information Technology for Economic and Clinical Health (HITECH) Act was passed to stimulate the adoption of electronic health records (EHR) and expand upon HIPAA's security and privacy laws concerning electronic protected health information (ePHI)[30].

3.3.1 HIPAA

The guidelines in HIPAA have been provided to protect the patient's electronic protected health information (ePHI) from its creation to its storage. HIPAA outlines the safeguards needed, defined as required or addressable, for different components of a computer network such as physical safeguards, technical safeguards, administrative safeguards, technical policies, and network security. Some simple examples of these safeguards are:

1. The data storage facility in which the server and/or database is kept must be secured and properly administered.
2. All data that is stored on hard drives, or the like, has to be encrypted, at rest.
3. All network connections between the data and its users, through the Internet, has to be secure and encrypted – Secure Socket Layer (SSL).
4. Healthcare provider or user login access to an application must be administered and managed.
5. Any access at any step, from the hardware and to the user application, must be tracked and logged, in order to pinpoint the source of any potential violations.

All Covered Entities or Business Associates are required to comply by the HIPAA Privacy Rule and are also subject to requests for audit reports by the HHS Office for Civil Rights (OCR). If the OCR finds that entities are in violation of the HIPAA Privacy Rule, they will impose fines and require them to provide a corrective action plan, which the OCR usually monitors for an extended period of time.

3.3.1.1 ePHI

Protected health information is the identifying data that a healthcare professional collects about a patient. Examples of this are medical history, test results, treatments, health conditions, insurance information, and personal information. When this data is converted into electronic form, such as through a practice management program, it is categorized as ePHI, which then becomes covered under HIPAA.

3.3.1.2 De-identification

Medical data can be beneficial to the population through comparative effectiveness studies and medical research. In order to facilitate these studies, HIPAA's Privacy Rule allows for the removal of personal identifiers from medical data through a process of de-identification. This is possible through two methods: the determination of a qualified expert or the removal of specific individual identifiers. Some of the identifying fields are names, specific dates, telephone numbers, addresses, social security numbers, health plan numbers, and account numbers. As long as the remaining fields cannot be traced back to the individual in any way, the resulting medical data is no longer considered protected health information. In this way, a medical data set can be used for research, such as training an AI model for diagnostic purposes, with no violation of HIPAA[31].

3.3.2 GDPR

The GDPR was implemented on May 25, 2018. The GDPR shifted the property of data from the businesses that collects them, to each individual person and defined the rights these individuals have regarding personal data. Personal data is defined by the GDPR as “any information relating to an identified or identifiable natural person (data subject); an identifiable natural person is one who can be identified, directly or indirectly, in particular by reference to an identifier such as a name, an identification number, location data, an online identifier or to one or more factors specific to the physical, physiological, genetic, mental, economic, cultural or social identity of that natural person.” Furthermore, the GDPR contains three additional types of health data, data concerning health, genetic data and biometric data. In order to process these data the following conditions must apply[47]:

1. Consent: The right to be informed about why data is required and how it will be used.
2. Access: The right to access all data and how it is being used, free of charge.
3. Correction: The right to correct inaccurate data.
4. The right to be forgotten: the right to erase one’s data.
5. Portability: The right to retrieve and use personal data across different services.

These regulations apply to any organization that processes the personal data of EU residents whether they are located in the EU or not. This means that most global companies must comply with the GDPR.

3.3.2.1 Anonymization and Pseudonymization

Similar to HIPPA’s de-identification, the GDPR has guidelines to make data unidentifiable; called anonymization or pseudonymization. By making it impossible to identify a person through medical data, data controllers and processor are permitted to process, publish and use medical data. Anonymization makes the data completely unidentifiable by removing personal identifiers such as name, address, job, postcode, etc. once the data is completely anonymized, the data will not fall within the scope of the GDPR, making it possible to use more freely. On the other hand,

pseudonymization replaces most identifying fields within the data record by changing them with pseudonyms. Pseudonymized data must be unidentifiable without the use of additional information, therefore, the GDPR advices organizations to store the additional information separately. In contrast to anonymization, pseudonymization still need to comply with the GDPR, but the usage of the data will be more flexible, and can be used beyond the purpose for which the data was originally collected. Since pseudonimized data can be de-identified, it must comply with the GDPR even when used for research. In contrast, anonymized data cannot be de-identified; therefore, it can be used for research purposes without violating the boundaries of the GDPR[50].

4. Circuli Platform

The Circuli platform works as a co-working ecosystem where users, typically data scientists, data providers, data labelers, and private and public entities, contribute to building AI diagnostic algorithms. The platform is built to accelerate medical AI diagnosis integration into the world. Current data science competition platforms, such as Kaggle, CrowdAI, and Alibaba Tianchi, focus only in the development of AI algorithms. In contrast, the Circuli platform requires the involvement of all necessary components of the AI algorithm production process, from data gathering and labeling, to building, training and testing AI algorithms. Furthermore, Circuli will exclusively accept projects with medical diagnostic purposes that could potentially aid general users, the healthcare industry, and society in general. Users are able to use the Circuli platform knowing exactly what to expect with much less navigation complications.

Circuli encourages and assists all of its platform users to participate in transparency and interpretability of automated diagnosis applications. We believe that creating such a platform will lead to a more common use of affordable and transparent automated medical diagnosis. The following explains the necessity and process of the Circuli platform.

4.1 The Circuli Community

4.1.1 Project Initiator

The Project Initiator is any person or private or public entity that wants to invest in the building of a medical AI diagnostic algorithm. The Project Initiator will decide on the desired AI diagnosis and write the project description. The project description will have an explanation of the funding, price, time limitation, evaluation parameters, and rewards regarding the project. Essentially, anyone can be an initiator as long as they have the necessary amount of CIL to invest in a project.

4.1.2 Medical Data Provider

Medical Data Providers (MDPs) are healthcare professionals and medical institutions that share anonymized or de-identified health data for research purposes. Large medical data sets are necessary for training and developing an AI algorithm. An algorithm will perform only as accurate as the information it is given to train with. MDPs will supply large amounts of raw anonymized medical data that the project needs and be paid according to the amount of data sets provided. Any healthcare organizations can be a data provider, whether they are government-funded or private, such as hospitals, private clinics, medical labs, pharmaceutical companies, etc. as long as they provide anonymized data to the platform.

4.1.2.1 Medical Data Privacy

The Circuli network believes in maintaining privacy of personal information, therefore only anonymized or de-identified data will be used. MDPs and other third party entities, such as

companies that use DApps, must follow HIPAA Privacy Rules when providing medical data in order to protect patient health data. De-identified health information does not and cannot be used to identify an individual and their individual health information. De-identified health information is no longer protected by the HIPAA Privacy Rule because it does not fall within the definition of protected health information (PHI)[31]. HIPAA Privacy Rule provides the standard for de-identification of PHI.

4.1.3 Medical Data Labeler

Medical Data Labelers (MDLs) are those who correctly label, check, and validate the medical data for every project on the platform. Physicians and radiologists are qualified to interpret medical images and label medical data. MDLs can access and work on either raw medical data, or already labeled medical data. Regarding already labeled data, the MDLs will check the labels and make any necessary edits if necessary, by suggesting a better label or delabeling inaccurate labeled data. Multiple MDLs are able look over the same labeled data in order to ensure accuracy of labels within the platform. Collecting accurate labeled data is vital for training AI algorithms, however it is labor intensive and time consuming. Therefore, MDLs on the Circuli platform will be incentivized according to the work provided.

4.1.4 AI Scientist

AI scientists will train and create an AI algorithm by using the labeled data provided for the project. Any AI scientist is able to build the AI algorithm requested for a given project. Various AI scientists can attempt to create an AI algorithm for the same project. The AI models that receive the best scores according to the evaluation parameters given by the Project Initiator will be rewarded.

4.2 Project Framework

The Project Initiator will submit the project description, which will be the core of the smart contract. The smart contract will act as rule sets used to verify and reward the process and result of the project, as well as a ledger for all transactions that takes place. The project description will contain information regarding the medical data and labels required, as well as what the objective of the AI algorithm is. Furthermore, it will specify the funding the project will receive and the rewards given to the participants. The more specific the project description, the more likely users will want to participate and the more efficiently participants will be able to work. In other words, if the project description lacks the necessary specifications, the project may not be able to be completed until necessary changes are made.

4.2.1 Project Objective

A Project Initiator will create a project if they find the necessity to create an AI algorithm for the diagnosis of a disease or condition, which can be identified through medical data and images. Project Initiators may have various reasons for wanting to create a project. It may be for research purposes or diagnostic purposes in a health institution with little resources. Once the

desired AI algorithm has been created, it can be shared on the platform amongst those who seek a faster, cheaper, and accurate diagnosis for the same condition. The algorithm can be used for different diagnostic applications by different health professionals.

4.2.2 Data

The data required for a project to be completed is determined by the Project Initiator. The Project Initiator will determine what kind of condition or disease must be identified. The appropriate medical images and data will be collected from MDPs and then labeled by the MDLs. Using the data and specifications provided; the AI scientist can train the AI algorithm to identify the patterns in the medical data or images. The project description must be clear enough for the MDPs and MDLs to understand the project objectives and provide as much data or labeling as possible.

4.2.3 Rewards

The Project Initiator will decide how much funding is necessary for the project and how much rewards all project participants earn. The decided amounts will be a part of the project description and uploaded onto the smart contract. If the Project Initiator's investment satisfies the essential MDLs, MDPs, and/or AI scientists and interested in the project, the project can begin. Once the project has been completed, the project participants will receive their rewards accordingly. This will enable broader participation of users and create a desire to interact on the platform. These incentives and rewards are important on the platform as they motivate participation and high performance. The members of the ecosystem must not only contribute to the successful building of AI algorithms, but also the ecosystem as a whole, in order to be fully incentivized.

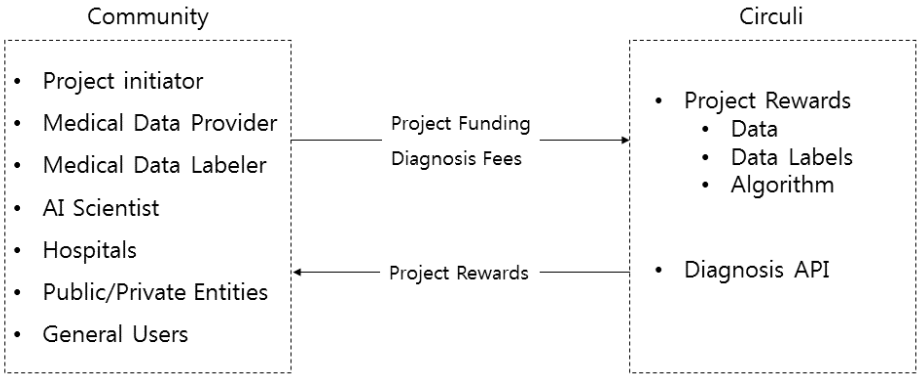

Figure 5: CIL Reward System

The Circuli ecosystem consists of Project Initiators, MDPs, MDLs, and AI scientists, who all receive some kind of incentive or reward for their participation on the platform, encouraging more and high quality usage. Project Initiators are motivated to create a project in order to solve a problem, an AI diagnostic algorithm for a particular disease or condition. MDPs are rewarded when they provide specific data and MDLs are rewarded for providing labels for data to train models. MDLs can also be rewarded when they improve, delabel, or prove irrelevancy of already

labeled data. AI scientists are incentivized when they build AI diagnostic algorithms. Ideally, every time there is an API call, a percentage will go to the scientists.

4.2.4 Evaluation Criteria

The evaluation criteria will rate raw data sets, data labels, and AI models provided by the project participants. The evaluation criteria will be determined and verified by the Circuli platform. If data labels are created by one MDL, other MDLs will be able to verify the labels and make necessary edits. If the labels made by the initial MDL contains errors, their rating may be reduced. AI algorithms will also undergo an evaluation regarding the accuracy and speed of the results made. Algorithms that perform more accurately and at a faster speed will be rewarded and utilized.

4.3 Project Process

4.3.1 Project Registration

The Project Initiator registers a project on the platform for other users to contribute and participate in the completion of a medical AI diagnosis. The Project Initiator provides the project description including the desired medical diagnosis model in the title. This information, along with the investment information, is logged onto a smart contract on the Circuli platform. The smart contract can only be made if the Project Initiator has the amount of the investment in the Circuli wallet.

4.3.2 Data collection

The Project Initiator will request data to MDPs, MDPs will provide the requested raw data and will be rewarded according to the amount of data provided. MDPs could also search and contribute to projects without a request from a Project Initiator as long as medical data is needed in a project.

4.3.3 Data Labeling

Once the data is provided, certified MDLs will start labeling the raw data in the Circuli platform according to the project description. MDLs are also able to re-label, delabel, or identify raw data that are not relevant to the project. All the data will be double-checked and verified by multiple labelers before entering the next phase. All participating MDLs will get rewarded.

4.3.4 AI Model Development

Once the data is labeled, AI scientists can experiment with different techniques and develop an algorithm that best fits the project description. During this phase, AI scientists may request for specific labels if the provided labeled data is unclear or unsatisfactory. Once

completed, AI scientists will be able to submit their algorithm to the platform to be evaluated according to the project evaluation criteria.

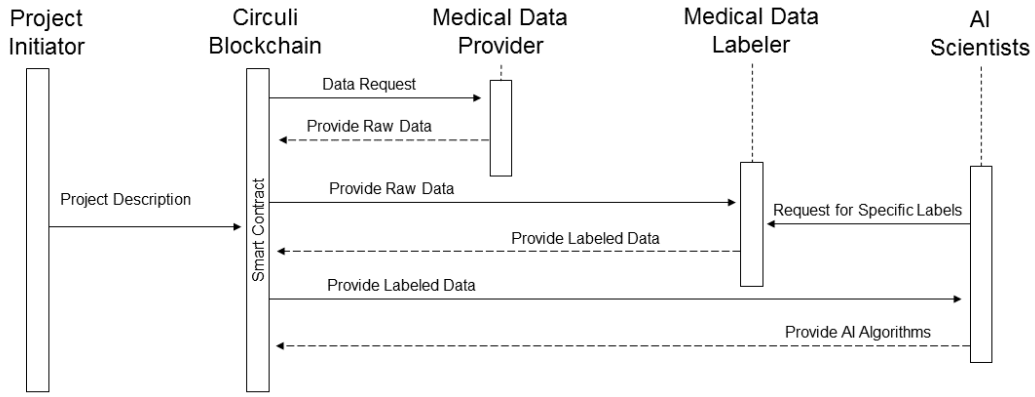

Figure 6: The Circuli Platform Process

5. Artificial Intelligence

Circuli believes that it is important to integrate AI technology into the platform to aid health professionals with their diagnosis process and help medical researchers with their studies. Circuli also would like to encourage the development and use of AI technology. Moreover, AI is not meant as a substitute for health professionals, but rather to be utilized to speed up the process and accuracy in detecting abnormalities and interpreting data. AI technology can be used for medical purposes and improve the healthcare industry, as well as improve society as a whole.

Much of medical data interpretation and data analysis involves the detection of patterns and areas of interest, whether in graphs or images. For electrocardiogram (ECG/EKG) tests, cardiologists look for patterns in a resulting EKG graph to determine the condition of a patient's heart. Deep learning, also known as deep neural networks (DNNs), is a subset of machine learning. Deep learning is when the neural networks have more than three layers of perceptrons, are programmed to detect, recognize, and classify patterns in data, and are able to learn high-leveled features in a non-linearly defined solution space. The complex algorithms mimic human brain functions, including Convolutional Neural Networks (CNNs), used for image recognition. This integrates easily with cardiologists' analyzation of EKGs, as the process involves detecting certain patterns in a patient's EKG.

Radiology is also a field in which AI integration is evident. Radiologists have always been among the first adopters of imaging and computing, including picture archiving and communications systems (PACS). Many radiologists are already using AI technology on a day to day basis. Traditionally, radiology training requires a great deal of time as it can be difficult to interpret different variations of medical images. In addition, the human eye cannot detect absolute luminance in images, making it hard to distinguish similar looking images. This detection can be made easier by using a deep learning algorithms approach, such as a CNNs. CNNs learn and detect patterns with similar, but at a greater depth than the human eye, as medical imaging sensors are capable of overcoming and resolving visual ambiguities through computational assumption.

Since neural networks learn and adapt from the data that is given, the machine learning model requires carefully chosen, high-quality labeled data in order to operate at its optimal level. Acquiring high-quality data can be difficult, therefore Circuli relies on MDPs and MDLs that are reliable and proper for the job. MDLs also have the ability to cross-check and improve each other’s work, removing room for data label error. A health professional will be able to use the AI technology to perform tasks such as: screening, diagnosing, monitoring progression of a disease, or confirming response to a treatment.

Circuli believes that this AI-based diagnostic technology benefits both patients and healthcare providers of all fields of medicine. Patients will benefit from accurate diagnoses, along with improvements regarding time and money constraints, as mentioned in section 2.1.2. The machine learning models will provide a tool to aid health professionals with their consultations by

detecting pathologies within an image or abnormalities in data through real-time computations. The technology and algorithms used in our device is explained in the following sections.

5.1 Neural Networks

Recent machine learning models are developed to have the structure of human neuroanatomy, where perceptrons (or neurons) and synapses are entangled in a deeply layered manner.

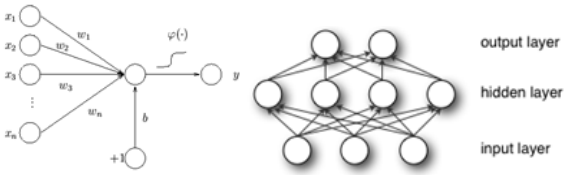

Figure 7: Examples of a single-layer perceptron (left) and an MLP model with a hidden layer (right).

The basic concept of a perceptron module was introduced in 1958 that computes the weighted sum of real-valued inputs which are put through a certain non-linear activation function to yield outputs. Such process can succinctly be described in an equation as:

$$\mathrm{y} = \phi\left(\sum_{\mathrm{i}=1}^{\mathrm{n}} \mathrm{w_i x_i} + \mathrm{b}\right) = \phi(w^t x + b),$$

Where **w** denotes the vector of weights, **x** is an *n*-dimensional vector of inputs, *b* is the bias and φ(·) is an activation function. The activation function is chosen to be the logistic sigmoid,1/(1 + e−x), the hyper-tangent, *tanh(x)*, or some various versions of the rectified linear unit functions (ReLU), max (0,x) . The perceptrons can be stacked to be a larger and more proficient structure to overcome the lack of mapping capability of a single perceptron, which is only able to represent an oriented ridge-like function regardless of activation function types. A typical multi-layered perceptron (MLP) network consists of a set of source ds forming the input layer, one or more hidden layers of computation nodes, and an output layer of nodes. The input signal propagates through the network layer-by-layer. The signal-flow of such a network with one hidden layer is shown on the right side of Figure 7 and can be written as:

$$\mathrm{y} = \mathrm{B}\phi(\mathrm{Ax} + \mathrm{a}) + b = f(x),$$

Where **x** is the input vector, φ(·) is the activation function, and **A** and **a** are, respectively, the weight matrix and the bias vector of the first layer, while **B** and **b** are of the last layer. Model 1 can become as complex as one wishes and is usually referred to as a neural network model because its characteristics are similar to that of human neural systems, shown in Figure 8.

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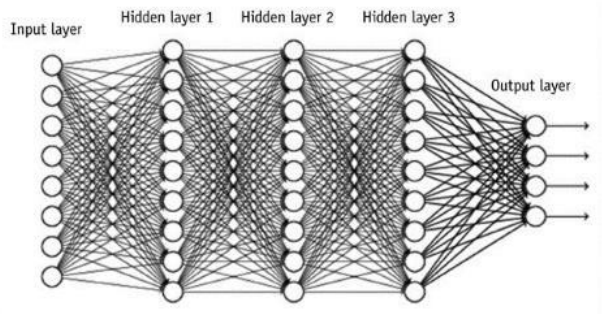


Figure 8: A Neural Network

By stacking multiple layers of the conventional perceptron structure, each node, at distinct layers of a deep neural network, extracts unique and complex features with different levels of abstraction[32]. Unlike other machine learning models, these neural models are allowed to learn high-level features in a non-linearly defined solution space[33].

The main goal of such network model is to, at least for many supervised learning cases, minimize the error of the outputs. Before training, the weight parameters of a neural network are initialized with randomness. At each iteration, a batch of inputs and targets is fed into the network. After that, the error between the each of the outputs of the network and its targets are calculated and then the network back-propagates each error value to its respective node, based on the chain rule.

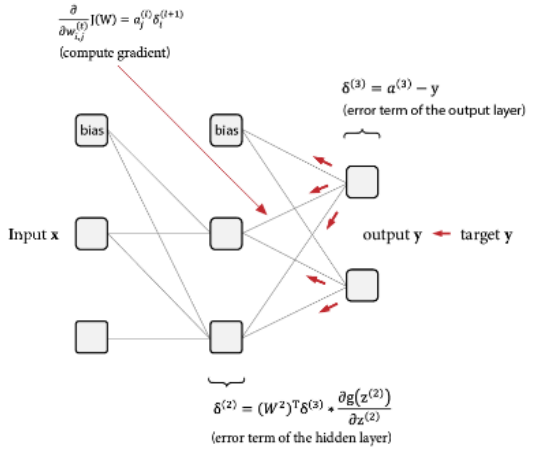


Figure 9: Illustration of the back-propagation process.

5.2 Convolutional Neural Network

As mentioned earlier, in the introduction of Section 5: Artificial Intelligence, the neural network structure can be further developed with convolutional kernels to aid in the interpretation of images and videos. The convolutional kernels are able to extract unique high-level visual features of its own while optimizing given loss functions. A human visual cortex is able to take visual input from the eyes and break it down into representative features in order for the brain to

process the information. The representation power, or the ability to efficiently condense visual features, of CNNs has already proved its ability to imitate this process of the visual cortex not only for many computer vision tasks with natural images[34] [35] [36] [37] [38], but also analysis on medical images[39] [40] [41]. CNNs are currently, and will be, used more widely in efforts to provide autonomous solutions that were not possible before its inception. Current state-of-the-art CNN methods for detecting target objects are able to accomplish highly satisfactory performance of the real-time detection of objects in streaming frames of sequential images[42] [37].

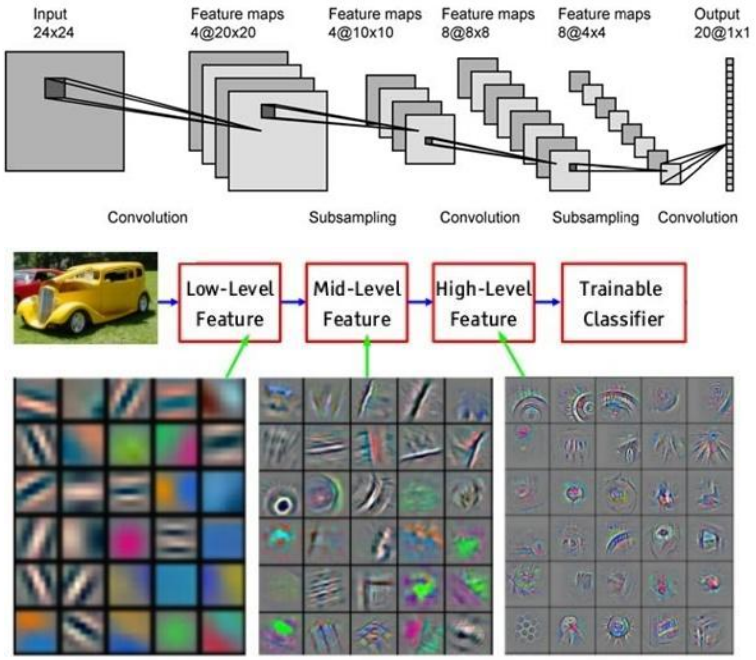


Figure 10: Convolutional Neural Network example

6. Blockchain

Blockchain, in its simplest form, is a growing list of records that uses cryptographic techniques to secure each record. After the advent of Bitcoin, it was more popularly known to be a decentralized, public ledger that permanently records verified transactions, or transfers, between two parties. After Ethereum introduced blockchain-based smart contracts, or "autonomous agents", it created the possibility of decentralized applications where use of applications, such as websites for social media, reviews, or auctions, would be automated, transparent, and open to the public.

Smart contracts allow the Circuli platform to be able to execute and verify processes, such as initiating a project or changing a project's status. Smart contracts are essentially programs set in the blockchain that executes based on its given parameters. When a smart contract receives an input, its code will autonomously run as it was created to do. Like any transaction on the blockchain, all calls to a smart contract will be logged onto the blockchain and be permanently stored in the ledger. Smart contracts allow for the blockchain, which normally cannot execute commands more complicated than a simple transfer, to be able to trustlessly execute the variety of commands needed to create feature-rich platforms.

The Circuli team is building its own platform that introduces an AI-based blockchain architecture which focuses on decentralized medical diagnosis and de-identified medical data sharing, which are managed by smart contracts. Diagnosis will be achieved by using medical machine learning algorithms on a medical data set. Furthermore, the blockchain allows decentralized medical diagnosis; meaning AI scientists and health facilities are able to exchange information with added security, privacy, and transparency.

Since the FDA has started approving machine learning applications for healthcare, official medical diagnosis through AI has become feasible, along with its insurability. But, in order to receive approval, the entire process will have to abide by the local laws. In the United States, if hospitals and insurance companies, and not patients themselves, were to use this feature, the entire diagnostic method will have to be compliant with HIPAA laws. This means that any electronic patient data, which will conceivably be exchanged between hospitals and insurance companies, will have to be processed and stored by nodes compliant with those laws. With this, the Circuli platform will be readily integrable with the extensive and well-established health industry.

6.1 Consensus

Nodes are essential for maintaining the integrity of the blockchain. They will support the network by maintaining a copy of the Circuli blockchain's ledger while processing and validating transactions and creating blocks to add to the Circuli blockchain. They will then be able to collect the transaction fees and block rewards in the form of CIL coins.

The Circuli blockchain is based on Proof of Stake (PoS) consensus. In PoS, blocks are 'minted' based on the amount of coins each validator (node) is willing to put up as collateral and 'staking' their coins[43]. The validators for the Circuli platform are the users who act as nodes. They will receive transaction fees for validating transactions, creating a clear economic incentive to hold coins for a long period of time. In addition to transaction fees, validators will receive block rewards for the validation of a new block. The block rewards will be provided from the Circuli reserve until the reserve reaches a certain value, then it will be provided through newly minted coins. When block rewards are formed from newly minted coins, Circuli will ensure that no more than 1% of the coin supply will be minted on an annual basis. With these incentives and subsequent stability of the blockchain, the PoS protocol provides increased protection from malicious attacks on the network. If a malicious attack were to happen, the protocol makes one extremely costly. Furthermore, validators only use a small amount of computing power because the main factors that influence their chances are the total number of their own coins and complexity of the network at the time.

PoS, in a way, is a more efficient system compared to Proof of Work (PoW) as it does not consume as much energy, but still performs speedy transactions, with more security. According to a research, Bitcoin transactions using the PoW protocol, may consume as much energy as the entire energy demand of Denmark in the next few years. Many blockchain developers believe that the PoS method is a more energy and cost efficient form of distributed consensus[44].

6.2 Nodes

The diagnostic nodes that populate the Circuli blockchain will be permissioned and secure in order to follow local healthcare laws, such as HIPAA of the United States. In order to ensure that the diagnostic results and its PHI are private, Circuli's diagnostic nodes will be capable of storing data alongside the blockchain. These nodes will store encrypted data locally and will be simultaneously distributed to other permissioned nodes in a method similar to peer-to-peer hypermedia protocols. Although data is stored in these nodes, the data will be encrypted and will be readable to only those with permission, similar to that of AES encryption. When this data gets referenced in the blockchain, only its address and hash will be written onto the blockchain. In this way, when the actual data is deleted from the data store, the hash will still remain on the blockchain solely to provide evidence of the transaction.

6.2.1 Data Storage

The amount of data required for machine learning tasks far surpasses the ideal size for blockchain transactions. For example, in order to train a machine learning algorithm, an ample amount of training data, mainly images, is required along with a validation dataset. The datasets, along with the storage of its training models and task execution data, will end up as a large chunk of data. So, the Circuli platform will be storing data off-chain, although still within nodes, and using encryption to secure the data. The off-chain data's address will then be referenced back into the blockchain through a transaction.

When a node uploads data for the blockchain, the platform will limitedly distribute and sync the encrypted data with other nodes that are connected to the Circuli network. This ensures availability of the data as a result of redundancy and high performance from a decentralized network's ability to scale. This connection protocol will be similar to current peer-to-peer file sharing protocols; in Circuli's case, it will be encrypted and permissioned. Once a file is uploaded and distributed, it will be referenced by a distributed hash table, which maps and locates files that are requested.

6.2.2 AES Encryption

AES, or a subset of it, was developed by Vincent Rijmen and Joan Daemen in a submission to the AES selection search conducted by the U.S. National Institute of Standards and Technology (NIST). It officially became the U.S. federal government's standard of encryption in 2002.

Encrypting involves taking a key and an input of bits (plaintext) and then processing it through an encryption algorithm (cipher), which then converts it into an encrypted output (ciphertext). AES encryption is based on a symmetric key encryption, which means that one secret key is used to both encrypt and decrypt data. This is in contrast to asymmetric key encryption, in which one public key is used to encrypt and a secret key is used to decrypt. Symmetric key encryption is also much faster than asymmetric key encryption as the former uses much simpler operations to encrypt data.

AES encryption operates on a 4 x 4 matrix of bytes based on a block size of 128 bits. This matrix is based on the input array, which is encrypted 16 bytes, or 128 bits, at a time[45].

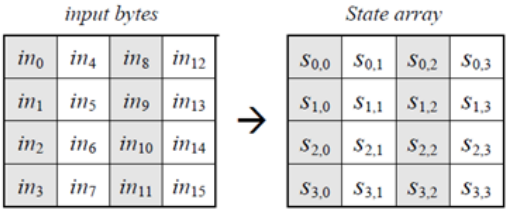


Figure 11: State array input

This matrix, or the state, is then put through the cipher, which consists of a number of rounds of processing steps dependent on the size of the encryption key, which can be 128, 192, or 256 bits. The cipher alters the state matrix with different transformation steps such as:

a. SubBytes
   - Each byte is replaced with a byte on a lookup table.

b. ShiftRows
   - The rows of the state are shifted cyclically.

c. MixColumns
   - The bytes of each column are combined using linear transformation.

d. AddRoundKey
   - The state matrix is combined with a block of the key.

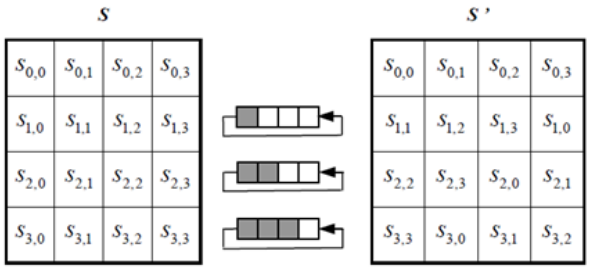


Figure 12: ShiftRows example

After all the blocks of inputs have been processed through the cipher, the output is stored on the database. This stored data will then only be decryptable, through the reverse process of the encryption, with the private key from the user. In this way, the data stored will be readable and accessible to only the owners of the private key.

6.2.2 Proxy Re-encryption

In a proxy re-encryption scheme, a form of public key encryption, a semi-trusted proxy server receives the ciphertext and converts the ciphertext into one that is decryptable by another key. This is not efficient for large data sets, but is used for smaller sets of permission-based data, such as those required by medical data labelers[46].

For example, a Project Initiator (PI) wants to send a fairly small amount of private data to a Medical Data Labeler (MDL). The PI encrypts the data with their public key and sends the ciphertext to a proxy server. The proxy server, without reading the original data, translates the ciphertext into another ciphertext that is decryptable by MDL's private key. This is possible through a re-encryption key that is provided to the proxy server by the PI. In a real use case, the data would be stored in a data store.

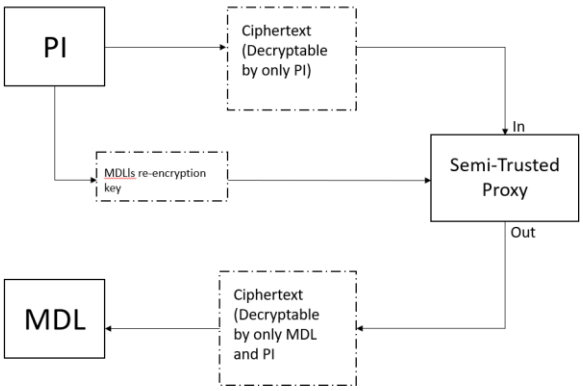


Figure 13: Proxy Re-Encryption

The re-encryption key creation process will be handled by a key management system (KMS). This system is responsible for key generation, distribution, and replacement and will act as an access control system for the sharing of proxy re-encrypted data.

7. Coin

CIL is a utility coin that will be necessary for transactions to occur on the Circuli platform. The Circuli ecosystem will consist of medical facilities, medical data researchers, research organizations, medical data labelers, AI scientists, and general users. Circuli ensures that all data will remain anonymous and secure in each transaction through data encryption. Circuli is an electronic exchange tool which disparate networks can use to share information with transparency and speed. Moreover, all users that have signed up for Circuli will have a digital wallet that will keep their CIL encrypted and secured. CIL transactions will only occur when all participating parties agree to the transaction.

CIL will initially be issued through the Ethereum blockchain following the ERC-20 Ethereum Token Standard. The token will be migrated onto the Circuli blockchain upon the completion of its platform. After the migration, CIL coins will be the only currency of exchange between the users of the Circuli platform.

CIL will become non-transferable on the Ethereum blockchain at the end of the ICO period in October of 2018.

7.1 Coin Economy

The Circuli platform is a decentralized open network that does not depend on any external economy and also one that does not discriminate in its access to participants. In other words, anyone who meets the minimum requirements will be able to provide services through the Circuli platform.

7.1.1 AI Diagnosis Development

In order to create an ecosystem for decentralized medical AI diagnosis, Circuli provides a community of users who work together for the development of medical AI diagnosis services. Each user has an important role in the community. Project Initiators register projects for the problem at hand. MDPs and MDLs provide necessary data for training and development of algorithms. AI scientists will build AI models and complete projects for Project Initiators. Since every market needs to make sure the price of its goods and services are set efficiently, the Circuli Team will help its users set fair prices in the beginning and later on let the community set fair prices through votes, a decentralized autonomous organization (DAO).

7.1.2 Diagnosis Platform

With the support of DApps and API calls from Circuli’s platform, companies will be able to develop a diagnostic service and collect their fees in CIL. Each time a user requests diagnostic

services regarding a specific diagnosis provided by the project's algorithm, the company will be able to receive a fee.

7.1.3 Block Rewards

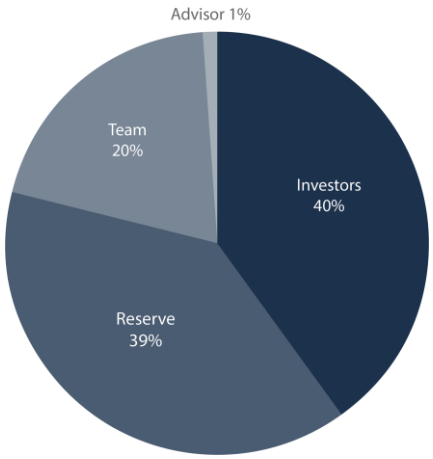
As mentioned before, medical AI diagnosis is the main focus of the Circuli platform. In order to develop an effective AI diagnosis algorithm, the algorithm must be trained and tested against a large dataset. The incentives, also called transaction fees, for nodes will be calculated based on the validation of transaction. This type of system, which rewards the consistent contribution of computing resources, encourages nodes to be readily available with their computing resources and ensures the constant flow of the blockchain.

The Circuli platform incentivizes users with CIL to guarantee its continued use and development. By using CIL for all payments, exchanges, and rewards within the network. This provides a mutually beneficial arrangement between the blockchain and its participants, which leads to the betterment of the entire Circuli medical diagnosis ecosystem.

7.2 Coin Sale Details

Coin Name	Circuli
Coin Symbol	CIL
Purchase Platform	Ethereum
Accepting Trading Currencies	Ether (ETH)
Total Amount	1 billion CIL
Market Price	$0.125
Hardcap	$20 million
Softcap	$4 million

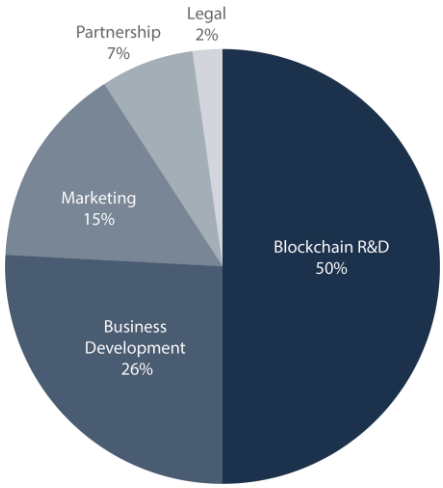
7.3 Coin Allocation



Circuli's reserves will be used to incentivize medical data providers, medical data labelers, and AI developers. Reserves will also be used for building the blockchain and operational purposes in pursuit of becoming a decentralized autonomous organization (DAO).

CIL for the Circuli project team will be locked for a 2-year vesting period. And the early investors and advisors will be required to lock CIL for 6 months and 12 months, accordingly.

7.4 Use of Funds



100% of all funds will be used to deploy the blockchain and execute the business development aspect of the Circuli network, which includes marketing/public relations, systemizing the legal framework, and partnerships.

8 Governance

The Circuli Team will be responsible for the adequate use of funds from any of the coins sold during the ICO and from the reserves. Initially, all responsibilities related to the Circuli platform and the network governance will be handled by the Circuli Team.

The use of funds received will be closely speculated by financial officers of Circuli. Circuli seeks to make any and all decisions and alterations with the consensus of the Board of Directors, investors, and the Circuli community in the future. The board members and business partners will be responsible for monitoring, reviewing and guiding the strategy of Circuli. Moreover, Circuli will actively communicate with the investors, business partners, and board members in order to tackle any possible ensuing misbehavior, inefficiency, and/or unproductiveness. Circuli seeks to strengthen company ethics with the intent of long-term success. In order to pursue the ambitious goal of making automated diagnosis widely available, Circuli's main priority and focus will always continue to be those who seek medical care, patients.

9 Team

Shin Woong Um - CEO and Founder

Shin Woong Um is a serial entrepreneur with over 10 years of experience in both hardware and software engineering. Shin founded Beforedent, Inc. in May of 2017 and has been working on early dental caries detection using AI technology. Shin previously co-founded an AI company in 2014, Coolio, Inc., which was backed by ETRI (Electronics and Telecommunications Research Institute). He was also involved in numerous government R&D projects such as the Busan Smart City Project, audio recognition project, media personalization and recommendations project, etc. Shin also founded Alida, a marketing and production firm, in 2011.

Dong Won Kim - Chief Medical Officer

Dong Won Kim holds a DDS degree from Yonsei University College of Dentistry. Dr. Kim has 42 years of experience of practicing dentistry, specializing in implant dentistry. He is responsible for providing clinical guidance and strategy for medical solutions. Dr. Kim graduated Seoul National University in 1974. He also studied at the Herman Ostrow School of Dentistry of USC from 2000 to 2002.

Jason Chung - Lead Engineer

Jason Chung is a technological leader with 8 over years of experience in software development. Jason is a computer science graduate of UC Berkeley and is a reliable, hands-on software developer who specializes in back-end and front-end development. Jason has was the CTO at Ga2oo LLC and software engineer at Flexfit LLC.

Hyunsoo Jang - Senior Engineer

Hyunsoo Jang has more than 24 years of experience as a hardware engineer. Hyunsoo worked as the deputy director for Daewoo Electronics, deputy head of department of technical assistance and product development at SigmaTel Korea, head of department and restructuring director at Hyundai Research Center, and various roles at multiple venture companies.

John (Hanyul) Yang - AI Scientist

John Yang is currently working as an AI scientists at Machine Intelligence and Pattern Analysis Laboratory (MIPAL) at Seoul National University. John received a Ph.D and M.S. degree in Intelligent Systems from Seoul National University. He has been working as a researcher and taking part in various intelligent systems projects since 2013.

Huixing Xu - Researcher

Huixing Xu is a Chinese national who studied medical dentistry at Changsha Medical University and is currently helping a healthcare instrument company's research regarding AI diagnosis in dentistry.

Seung Hwan Lee - Business Development

Seung is Circuli's business developer who previously worked as a business developer and business analyst at Hyperconnect Inc., a social discovery company that develops software and mobile applications based on WebRTC technology. Their application, Azar, has over 100 million downloads worldwide.

Yuree (Amy) Chong- Business Development

Amy is Circuli's business developer who loves challenges and is an independent learner interested in the latest technological advancements. Amy studied international relations and is multilingual; she speaks Korean, English and Mandarin Chinese.

Ji Hwan Park - Designer

Ji Hwan is the lead designer for the Circuli project. Ji Hwan has experience working in web design, industrial and product design. He is currently working as Circuli's UI/UX and web designer.

Advisors

Chris Suh

Chris Suh, CPA, was the former Chief Risk Officer and Korea Treasurer at Goldman Sachs Korea. He brings more than 16 years of funding, capital management, FX and liquidity management experience and expertise to the project. He is also an active business angel and start-up advisor. Prior to engaging Circuli project, he has advised Telcoin and Bezant projects and made substantial contribution to their successful ICOs and treasury flow set up.

Yongbeom Kim

Yongbeom Kim is an attorney at law and partner at OhKims law firm and holds a DDM. He specializes in medical and technology-focused legal services, primarily involving blockchain

technology and ICO legal implications. Yongbeom holds both a JD and DDM; he graduated from Yonsei University College of Dentistry and Korea University Law School. He provides consultation for corporate cases such as investment contracts, ICT contracts, technology transfer contracts, and corporate legal affairs.

Risks

The purchase of CIL carries with it significant risks, including, but not limited to, the risks described below. Prior to acquiring CIL, it is recommended that every potential purchaser carefully consider the risks detailed in this White Paper and, to the extent necessary, consult a lawyer, accountant, and/or tax professional prior to deciding whether to purchase CIL.

Please further note that Circuli may be subject to other risks not foreseen by its team at this time.

CIL Wallet Limitations

CIL will be stored in a wallet, and can only be accessed with a password the purchaser creates. Purchasers must safely store their password in one or more backup locations that are separated from the primary location. Not maintaining an accurate record of their password or having weak protection of the password may lead to the loss of CIL.

Private Keys

Coins purchased will be stored in a wallet, which requires a private key, or a combination of private keys, for access. Accordingly, loss of requisite private key(s) associated with the purchaser's wallet storing the coins will result in loss of such coins. Moreover, any third party that gains access to such private key(s), including by gaining access to login credentials of a hosted wallet purchaser uses, may be able to misappropriate purchaser's CIL. Circuli is not responsible for and shall be held harmless in respect of any such losses.

Development of Circuli Platform

The purchaser recognizes that some of the services and functions under the Circuli platform is currently under development and may undergo significant changes before release. The purchaser acknowledges that any expectations regarding the Circuli platform may not be met for any number of reasons.

Risk of Dissolution of Company

It is possible that, due to any number of reasons, including, but not limited to, an unfavorable fluctuation in the value of Ethereum, Bitcoin, or other cryptocurrency and fiat currencies, decrease in the coins utility due to negative adoption of the Circuli platform, the failure of commercial relationships, or intellectual property ownership challenges, the Circuli platform may no longer be viable to operate and the Circuli company may dissolve.

Dependence on Computer Infrastructure

Circuli's dependence on functioning software applications, computer hardware, and the Internet implies that Circuli can offer no assurances that a system failure would not adversely affect the use of CIL. Despite Circuli's implementation of all reasonable network security measures, its processing centers are vulnerable to computer viruses, physical, or electronic break-ins or other disruptions of a similar nature. Computer viruses, break-ins or other disruptions caused by third parties may result in interruption, delay or suspension of services, which would limit the use of the CIL.

Smart Contract Limitations

Smart contract technology is still in its early stages of development, and its application is of experimental nature. This may carry significant operational, technological, regulatory, reputational, and financial risks. Consequently, although the audit conducted by independent third party increases the level of security, reliability, and accuracy, this audit cannot serve as any form of warranty, including any expressed or implied warranty that the Circuli Smart Contract is fit for purpose or that it contains no flaws, vulnerabilities, or issues which could cause technical problems or the complete loss of CIL.

Regulatory & Litigation Risks

The regulatory status of CIL, distributed ledger technology and initial coin offerings is unclear or unsettled in many jurisdictions. It is difficult to predict how or whether regulatory agencies may apply existing regulations with respect to such technology and its applications, including Circuli platform and CIL. It is likewise difficult to predict how or whether legislatures or regulatory agencies may implement changes to law and regulation affecting distributed ledger technology and its applications Circuli platform and CIL in various ways. There exists a significant risk of litigation due to the current ambiguity concerning the regulatory environment across many regions.

Furthermore, blockchain technology, including, but not limited to, the issue of coins, may be a new concept in some jurisdictions, which may then apply existing laws or introduce new regulations regarding Blockchain technology-based applications, and such regulations may conflict with the current CIL smart contract setup and CIL concept. This may result in the need to make substantial modifications to the CIL smart contract, including, but not limited to, its termination, the loss of CIL, and the suspension or termination of all CIL functions.

Circuli may cease operations in a jurisdiction in the event that regulatory actions, or changes to law or regulation, make it illegal to operate in such jurisdiction, or commercially undesirable to obtain the necessary approvals to operate in such jurisdiction.

Delayed Projects

Although the Circuli Team believes that its assumptions underlying its forward-looking statements are reasonable, any of these may prove to be inaccurate. As a result, the Circuli Team can offer no assurances that the forward-looking statements contained in this White Paper will prove to be accurate. The CIL purchaser must understand that while the Circuli Team will make the best efforts to release the Circuli platform on time, it is possible the official release may be delayed for any number of reasons.

Force Majeure

Circuli's performance may be interrupted, suspended, or delayed due to force majeure circumstances. For the purposes of this White Paper, force majeure shall mean extraordinary events and circumstances which could not be prevented by Circuli and shall include: acts of nature, wars, armed conflicts, mass civil disorders, industrial actions, epidemics, lockouts, slowdowns, prolonged shortage or other failures of energy supplies or communication service, acts of municipal, state or federal governmental agencies, other circumstances beyond Circuli's control, which were not existent at the time of the Circuli White Paper release. If such circumstances occur prior to the issue of CIL and Circuli is unable to issue CIL within one month from the projected date, the escrow agent may issue a refund at the request of the CIL purchaser. The refund will be issued in the original form of payment to the same digital wallet or bank account where the funds were transferred from.

Value of the CIL

As with other Cryptocurrency, whether token or coin, the value of CIL may fluctuate significantly and become reduced in value for any number of reasons including but not limited to, the Cryptocurrency market condition, political or geographical reasons, changes of regulations, technical reasons, and supply and demand. Circuli does not guarantee any specific value over any specific period of time. Circuli shall not be held responsible for any change in the value of CIL.

Competition Risks

With an increasing number of players entering blockchain, the market is becoming increasingly competitive. It is possible that alternative networks could be established that utilize the same or similar code and protocol underlying Circuli and/or CIL to recreate similar facilities. Circuli may be required to compete with these alternative networks, which could negatively impact Circuli and/or CIL. The trend of future competition is still unclear.

Risk of Alternative

Following the ICO and the development of the initial version of the Circuli platform, it is possible

that alternative applications could be established, which use the same open source code and protocol underlying the Circuli platform. The official Circuli platform may compete with these alternative, unofficial CIL based applications, which could potentially negatively impact the Circuli platform and CIL, including its value.

Rights, Functionality or Features

CIL do not have any rights, uses, purpose, attributes, functionalities or features, expressed or implied, including, without limitation, any uses, purposes, attributes, functionalities or features on the platform, other than those strictly provided in the White Paper.

Risks Associated with Markets for CIL

Prior to the ICO, there has been no public market for the CIL. Although the Circuli Team will use reasonable endeavors to seek the approval for availability of the CIL for trading on a cryptocurrency exchange, there is no assurance that such approval will be obtained. Furthermore, even if such approval is granted by a cryptocurrency exchange, there is no assurance that an active or liquid trading market for CIL will develop, or if developed, will be sustained after CIL have been made available for trading on such cryptocurrency exchange. There is also no assurance that the market price of CIL will not decline below the original purchase price. The purchase price may not be indicative of the market price of CIL after they have been made available for trading on a cryptocurrency exchange.

Insufficient Interest

It is possible that Circuli platform will not be used by a large number of individuals, companies and other entities or that there will be limited public interest. Such a lack of use or interest could negatively impact the development of Circuli platform.

Uninsured Losses

Unlike bank accounts or accounts at some other financial institutions, CIL are uninsured unless the purchaser specifically obtain private insurance to insure them. Thus, in the event of loss or loss of coin value, there is no public insurer or private insurance arranged by Circuli, to offer recourse to the holder.

Taxes

CIL holders may be required to pay taxes associated with the transactions contemplated herein, whether in the United States of America or in their home countries. Purchasers of CIL must seek their own tax advice in connection with purchasing CIL, which may result in adverse tax consequences to purchasers of CIL, including withholding taxes, income taxes, and tax reporting requirements. It will be a sole responsibility of CIL holders to comply with the tax laws of the United States of America and other jurisdictions applicable to them and pay relevant taxes.

Dependence on Ethereum Protocol

The purchase of CIL during the ICO period will be done on the Ethereum blockchain platform. As such, any malfunction, breakdown, abandonment or other unexpected circumstances of the Ethereum protocol during this time may impact the purchaser's ability to transfer or securely hold CIL. Furthermore, advances in cryptography, or technical advances such as the development of quantum computing, could present risks to CIL and the wallet by rendering ineffective the cryptographic consensus mechanism that underpins the Ethereum protocol.

Lack of Funds from ICO Proceeds

Circuli may not reach the target sale amount and may not have sufficient funds to execute its business plan. Furthermore, Circuli may not succeed in creating the necessary momentum and acceptance for CIL, which may result in low liquidity and depletion of trades.

Hacking and Security Weakness Risks

Hackers or other malicious groups or organizations may attempt to interfere with CIL in a variety of ways, including, but not limited to, malware attacks, denial of service attacks, consensus-based attacks, Sybil attacks, smurfing, and spoofing. Furthermore, because Circuli is based on open-source software, there is a risk that a third party or a member of the Circuli Team may intentionally or unintentionally introduce weaknesses into the core infrastructure of Circuli, which could negatively affect it and CIL, including the utility of CIL.

Know Your Customer and Anti-Money Laundering Policy

Circuli's "Know Your Customer" and Anti-Money Laundering Policy (KYC/AML Policy) is designed to prevent and mitigate any possible risks of the firm being used to facilitate financial crime or any kind of illegal activity.

Policy Scope

This Policy applies to everyone who wishes to join the Circuli ecosystem, as well as people who are already part of the Circuli ecosystem.

What is Money Laundering?

Money laundering is the generic term used to describe the process by which criminals disguise the original ownership and control of the proceeds of criminal conduct by making such proceeds appear to have been derived from a legitimate source.

Verification

Circuli will implement one of the most widely used international standards for preventing illegal activity, the customer due diligence (CDD). According to the CDD, Circuli establishes its own verification procedures within the standards of KYC/AML frameworks. The identity verification will hold as follows:

Identity verification requires every Circuli user to provide a reliable and independent source of identification document, data or information such as passport, national ID, bank statements, etc.

Circuli will take the necessary steps to confirm the authenticity of the data and document provided by the user. All legal methods for confirming the authenticity will be used. Circuli reserves the right to investigate users who have been determined to be suspicious. Furthermore, Circuli reserves the right to verify user's identity on an ongoing basis, especially when the data has been changed or their activity seemed to be unusual or suspicious. Furthermore, Circuli reserves the right to request Up-to-date data or documents from users that have already passed the identity verification process in the past.

Circuli reserves the right to collect user's identification information and data for the KYC/AML policy purposes. All of the documents and information collected from the users will be stored and protected strictly in accordance with our Privacy Policy and related regulations.

Once the identity of the user has been confirmed, Circuli can be removed from potential legal liability in a situation where its services are used to commit an illegal activity.

Compliance Officer

The Compliance Officer is a person, authorized by Circuli, whose duty is to ensure the effective implementation and enforcement of the KYC/AML Policy. The Compliance Officer is responsible for supervising all aspects of Circuli's anti-money laundering and counter-terrorist financing, including, but not limited to: (1) Collecting users' identification information and data. (2) Establishing, updating, and implementing internal policies and procedures for the completion, review, submission, and retention of all reports and records required under the applicable laws and regulations. (3) Monitoring transactions and investigating any significant deviations from normal activity. (4) Implementing a records management system for appropriate storage and retrieval of documents, files, forms, and logs. (5) Updating risk assessment regularly. (6) Providing law enforcement with information as required under the applicable laws and regulations.

The Compliance Officer is entitled to interact with law enforcement agencies, which are involved in the prevention of money laundering, terrorist financing, and other illegal activities, in the case a user is suspected of being involved in illegal activities.

Monitoring Transactions

Users will be known not only by the identity verification but, more importantly, by analyzing their transactional patterns. In other words, Circuli relies on data analysis as a risk-assessment and suspicion detection tool. Circuli performs a variety of compliance-related tasks, including capturing data, filtering, record-keeping, investigation management, and reporting. System functionalities include: (1) Daily check of users from known blacklists, such as the List of Specially Designated Nationals and Blocked Persons maintained by the U.S. Treasury Department's Office of Foreign Assets Control (OFAC), placement of users on watch and service blacklists, opening of cases for investigations where needed, sending of internal communications and filling out statutory reports, if applicable. (2) Case and document management.

With regard to the KYC/AML Policy, Circuli will monitor all transactions and reserves the right to ensure that transactions of suspicious nature are reported to the proper law enforcement agency through the Compliance Officer, request the user to provide any additional information and documents in case of suspicious transactions and suspend, or terminate an account when Circuli has reasonable suspicion that such user is engaged in illegal activity.

The above list is not exhaustive and the Compliance Officer will monitor users' transactions on a daily basis in order to define whether such transactions are to be reported and treated as suspicious activities.

Risk Assessment

Circuli, in line with the international requirements, has adopted a risk-based approach to combating money laundering and terrorist financing. By adopting a risk-based approach, Circuli is able to ensure that measures to prevent or mitigate money laundering and terrorist financing are commensurate to the identified risks. This will allow resources to be allocated in the most efficient ways. The principle is that resources should be directed in accordance with priorities so that the greatest risks receive the highest attention.

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