Implementing Triple Entry Accounting System with π Account on Block-chain Protocol

Wang-Bor Chen[1], Ching-Tsorng Tsai[2], Jasper Tahnk[3]

[1] Bordao Co., Taiwan
[2] Department of Computer Science, Tunghai University, Taiwan
[3] Chemical Engineering, University of Rochester, USA
wangbor.chen@gmail.com, cttsai@thu.edu.tw, jaspertahnk@gmail.com

Abstract

Lao Tzu ("老子") described in the Tao Te Ching ("道德經") that "The Tao begat one". One begat two, Two begat three, and "three begat the myriad things". "Three" is a magic number in Chinese society, and we believe that "triple"-entry accounting can also magically connect to the world. We have verified that all accounting activities can be recorded on blockchain through the triple-entry accounting design, and transaction with layer-by-layer journal entry could connect all economic activities of the world each other. In this paper we redefine the term "triple entry accounting" with blockchain protocol and proposes new π-account concept to visualize and analyze the journal entry of accounting book, and gain full picture of economic activity on blockchain. We also introduce hierarchical deterministic structure on blockchain protocol mapping into account book structure in compliance with international accounting standard. At the same time, we have verified that the distributed ledger technology has completely implement both internal and external straight through processing. In the near future, we will have a visual tool to exam the results of our research through data structure of triple-entry accounting.

Keywords: Bitcoin, Triple entry accounting, Hierarchical deterministic structure, Block-chain protocol

1 Introduction

Modern accounting system operates in a diverse and distributed environment cross multi-entity, a variety of financial instruments, diversified commercial contracts and different governance. There exists many uncertainties which increase audit costs and operational risk. During the transaction life cycle of the accounting system, ensure that the accounting process correctly reflects all economic and business activities [1]. The front-end office, middle office of risk management and back-end office of accounting systems should operate mutually to avoid conflicts of interest, minimize risks and maximize profits.

With the progress of Internet and technology, "open ledger" is constructed by block-chain protocol. It provides a technical solution for sharing ledger with relative anonymity and trust-less computing network. In the block-chain protocol, distributed ledger technology (or DLT) provides accounting infrastructure to peer to peer society. The revolution of modern accounting system of auditing, reconciliation and consistency on "open ledger" environment therefore could be feasible [4].

2 Problem Formulation

2.1 Bookkeeping

In the development and evolution of human civilization, transactions or events of value exchange are recorded through bookkeeping. Any changes in the assets, liabilities and capital of economic entities resulting from economic transactions are recorded in a time series. The earliest single-entry accounting structure is a simple and incomplete bookkeeping method that relies on single entity to maintain financial information. Single-entry bookkeeping records each economic activity in a single aspect and may produce many prejudices, risks and errors, such as the inability to express cash receipts, payments, accounts for settlement, debt information and so on. From the documentation point of view, single-entry accounting is a memorandum book [2].

Compared with the single-entry accounting structure, the modern accounting system developed a double-entry accounting (also known as double-entry bookkeeping) structure in which transactions are recorded in at least two separated debit and credit accounts, and the total amount of the debit and credit account of the transaction is equal. Based on the balance between assets and equity of each economic business or transaction in accounting term, it must be registered in two or more interconnected accounts with

*Corresponding Author: Ching-Tsorng Tsai; E-mail: cttsai@thu.edu.tw
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equal amounts to reflect the results of changes in a comprehensive and interconnected manner, and can be audited internally and externally.

Nevertheless, the biggest issue with double-entry accounting is that bookkeeping and accounting statements are prepared by a single accounting entity, and most economic operations or business activities are participated by two or more accounting entities, such as bank deposit account records stored in external banks. Therefore, the accounting process must check accounts regularly, including accounting vouchers with original ones, bank deposit journals with accounting vouchers and so on, to ensure the authenticity and correctness of the accounting records and statements.

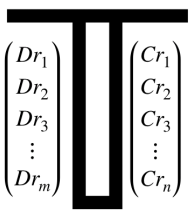
Another issue is the local regulation of compliance with the accounting principles of international standard like IFRS [5]. Accounting transactions, that is, accounting items should be listed in accordance with International Financial Reporting Standards. Moreover, the accounting posting and profit & loss statement must be audited through internal accounting procedures and comments from external accountants. The gap of different posting methods on the compliance of accounting standards even generate accounting fraud and increase operational risk costs.

2.2 Triple Entry Accounting with Block-chain Protocol

A journal entry is a record of the business transactions in the accounting books. Modern double-entry accounting properly documented journal entry consists of the correct date, amounts to be debited & credited and description of the transaction [11], as shown in the following equation, each journal entry includes two sets of entry pairs (eq. 1).

$$\begin{aligned} &DoubleEntry(Dr_x, Cr_y) \\ &= (Dr_1, Dr_2, ..., Dr_m, Cr_1, Cr_2, ..., Cr_n) \end{aligned} \quad \textbf{(1)}$$

The accounting system provides a direct visual expression of T accounts to present accounting records for double-entry accounting system. A T account has a left side and a right side, called "debit" and "credit" respectively. A journal entry of transaction presents as T- account, as figure shown, where the total amount of Dr account should equal to Cr account. The accountant draws a T account step by step to analyze the accounting entries (Figure 1).



Where $\sum_{x=1}^{m} Dr_x = \sum_{y=1}^{n} Cr_y$

Figure 1. T account to analyze the accounting entries

A journal entry of T account is the important step in the accounting cycle to breakdown financial transactions to each event in detail. The financial transaction of among the parties maintain at least two accounts in their own accounting book or called "common ledger", as figure shown, respectably (Figure 2).

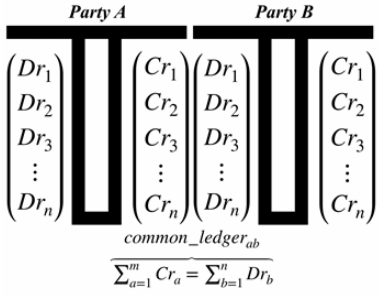


Figure 2. Common Ledger

For example *party A* make transaction, buying a cup of coffee at *party B's* coffee shop. Both parties will make journal entry reconciliation with "*common ledger*" and should make it consistency. Later on it can be audited or reconciled. The inconsistency of these two general ledger or *common ledger* are often caused by accounting fraud.

The term triple-entry accounting first appeared in 1986 by Yuji Ijiri with a third layer of entries called *trebit.* Grigg in 2005 [3] redefined the term with blockchain protocol. We continued Grigg's research and redefine the triple-entry accounting structure and **π** account to make ledger more readable on blockchain. At the same time, an intuitive and visual accounting tools could be designed to draw full picture of economic world.

In this paper we define the term ***"triple-entry accounting with blockchain protocol" (named in Chinese*** 三式記帳法***) as three accounting entries with two different transactions in multiple accounting entities*** (Figure 3).

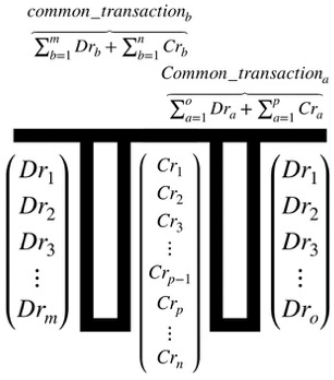


Figure 3. Three accounting entries with two different transactions in multiple accounting entities.

Triple-entry accounting system keep a "common transaction" on blockchain between the two double-entry systems documenting that the transactions in the

two systems. This "common transaction" ensures the consistency and compliance of the chart of accounts, accounting posting, accounting principles and accounting standard like IAS or IFRS. In one single view of "common transaction", it is no longer necessary for the traditional double-entry accounting system to serve as the reconciliation of accounting statement, and there is no need to exchange accounting records between two different systems, or intermediary systems for accounting reconciliation.

The main purpose is to grab the business activities of these two different transactions, so as to analyze related transactions and accounts in series to make accounting accuracy and traceability. In order to prevent the double-spending problem, blocks chained in chronological order are formulated in the blockchain protocol. Each block contains the latest unconfirmed transactions, and input-script of transaction must correspond to the previous transaction of unspent-output-script UTXO (Figure 4).

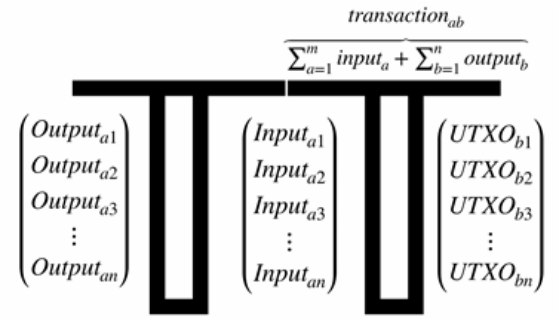


Figure 4. Unspent-output-script UTXO

Each transaction chained in specific block form a "distributed ledger", and accounts with transactions are encrypted to protect privacy and security. Encrypted accounts and confirmed transactions are well stored in distributed nodes, without the need for centralized services or confirmation from trusted nodes. Such blockchain protocol provides a great data structure and relational scheme of "triple-entry accounting", which is used for tracking related transactions and accounts, such as anti-money laundering (AML) or know your customer. Through the data structure of the triple-entry accounting, we can track all transaction step by step and find the relevance of the transaction and the account (Figure 5)

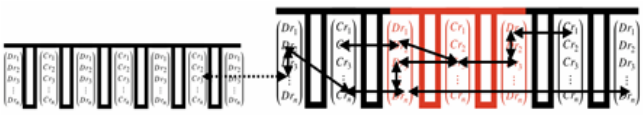


Figure 5. AML Transaction tracking

2.3 Transaction

Transactions on blockchain protocol are the ledger that encode the transfer of value among participants. A single transaction on blockchain can include multiple outputs and inputs. It is the form of a transaction which is hashed to create the unique transaction id and then broadcast between peers in a serialized byte format to blockchain network. Ultimately, a block contains the transaction checking the format of blockchain consensus rules and published to network [10].

Since blockchain protocol maintains single hyper ledger view of transactions and each inputs-script spends outputs-script which also called unspent transaction output or UTXO from a previous transaction, we can represent input as flow out or "-" and output as flow in or "+" from cash flow point of view. Comparing to double entry accounting, debit and credit accounts have different meaning depended on asset or liability side.

In this paper we will maintain transaction as a (input, output)-pair aspect with blockchain protocol in one single account code (eq. 2).

$$Transaction(input_x, output_y) = (vn_1, vn_2, ..., vn_m, vout_1, vout_2, ..., vout_n) \quad \textbf{(2)}$$

Each input-script spends an UTXO from a previous transaction which linked all related transactions together, and therefore all related transactions on the blockchain can be tracked. We can transform it as π account which simplified view of what is contained in a transaction.

2.4 π Account for Triple Ledger Accounting

We introduce new concept of π account to present triple-entry accounting system. The π account is a visual representation of individual accounts that looks like a "π" or "Π" and can be easily tracked and represented. Each π account in triple entry accounting represents two traditional T- accounts in double entry accounting as it should be (eq. 3):

$$\pi_{account} = T_{account} + T_{account} \quad \textbf{(3)}$$

Pi or "π" or "Π" is an infinite and irrational decimal **[6]** which brings "π account" two special meaning to triple ledger accounting system. First, *infinity* represents triple ledger accounting system is boundless or endless [7]. Second, it records each economic activities as transaction without cycles like *irrational* π on blockchain protocol.

We can express *infinity π account* with triple entry accounting model as transaction in accounting pair*(Dr,Cr)* as below (Figure 6).

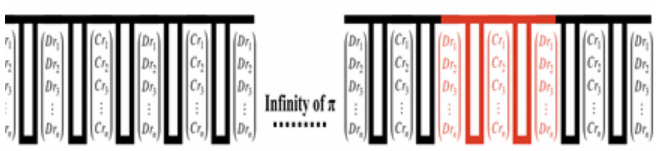


Figure 6. Infinity π account with triple entry accounting model

In this paper, based on view of flow in and out and concept with blockchain protocol, we show infinity π account with triple entry accounting model as transaction in set of input and set of output on blockchain protocol (Figure 7).

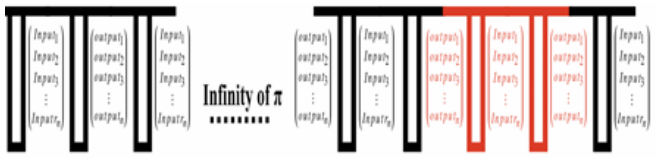


Figure 7. Transaction in set of input and set of output on blockchain protocol

In triple-entry accounting, two transactions are considered to affect at least three of accounts or address. One account get a debit entry, while the second get a credit entry and the third get a debit entry to record each transaction that occurs.

2.5 Hierarchical Deterministic Structure

In practice, in accordance with the requirements of accounting entities and accounting ledgers, we need to implement a hierarchical deterministic tree structure on blockchain to ensure that it corresponds to the book structure and accounting classification in triple entry accounting system, and at the same time provides the authority and assess right of asset for portfolio management .

Bitcoin improvement proposal [8] provides a tree structure of Hierarchical Deterministic address, which uses an entropy (or seed) to generate a master key pair, also called a tree root, and it could generates multiple sets of child key at the next level, and the child key pairs of the second layer can generate multiple child key pairs on the third layer and so on. The hierarchical deterministic structure is composed of one or more hierarchical keys, and each node corresponds to a combination mapping into accounting book structure. Each node has a key pair (public key & private key) and chain code to obtain the transaction control rights corresponding to the asset allocation.

The main purpose of maintaining the tree structure is that a child node can only belong to one parent node. The parent node has the key to generate the child node, which means that the parent node has the control rights of all child nodes. This corresponds to the portfolio of accounting book, and each sub-account or child node has absolute independence from other sub- accounts. Nodes of hierarchical deterministic tree are divided into independent sets, each set is also a tree structure, and mapping into the portfolio structure, entity , organization structure, assets class, risk structure, and accounting purpose.

3 Problem Solution

3.1 Book Structure Design for Accounting Purpose

In international accounting standards or IAS, each transaction, even same financial product, will behaved in different ways according to the different accounting purposes and principle. A financial transaction is often due to different trading purpose, and there will be different P&L scheme to express the accounting statement, such as the transaction for trading purpose or the transaction held to maturity. Even more, the sequence of transactions with each accounting purpose group will affect the calculation of profit and loss.

For example, for financial transactions, the compliance requirements of the I*nternational Accounting Standards No. 39* are divided into four major categories of transactions according to the trading purpose, and it strictly stipulates that different accounting categories cannot be transferred arbitrarily. Afterwards, the principle of these compliance rules only be examined through comprehensive internal & external auditor and computer system in double-entry accounting environment. Nevertheless, the normalization of accounting record such as *counter-party id*, separated ledger, operational Risk, and individual accounting principle in different systems greatly increases the difficulty of auditing and accounting accuracy. This means that it is very important to establish a blockchain architecture with triple entry accounting structure that make data trackable and consistency.

We learn that implementing accounting book structure with blockchain protocol in triple entry accounting should cover key implementation of hierarchical deterministic technology or HDT. For example in bitcoin network, the hierarchy path of bitcoin address to five levels based on *Bitcoin Improvement Proposal BIP 32* are defined for common usage : "*m / purpose' / coin_type' / account' / change / address_index"* which "purpose" is a constant set to 44' and coin_type are used for crypto-currency such as Bitcoin [9]. Each industry has a different account book structure design. It is very important that conforms to the accounting table according to the characteristics of the industry. We are trying to establish a universal book structure design principle covering a wide range.

According to the characteristics of the industry, each industry has a different account book structure design. The hierarchy on blockchain mapping into accounting book structure are proposed comprehensively based on the principle as below:

1. Classified by financial market products and services: financial product business expansion includes capital transactions, foreign exchange forex, money markets, bond, bill, stock, and derivatives.

2. Short-term and long-term capital requirement: Identify capital and liquidity management with risk management

3. Local currency and foreign currency portfolios: multi-currency transactions, dividing country risk, regional risk and foreign exchange risk.

4. Liquidity management: according to liquidity mapping into function unit such as liquidity reserves and forward positions.

5. By financial traders of entity organizations: according to trading desk like money market desk, forex desk, fixed income desk, overnight desk, derivative desk and sales desk.

6. By internal entities and function unit: like investment banking unit, Interbank unit, asset management unit, overseas Branches, domestic branches and so on.

7. Accounting to guideline and compliance with international accounting standards: two categories of trading and investment purpose.

8. By branch, financial supply chain, group customer, region or profit center.

9. Segmentation of their trading positions in the financial market: like market risk, credit risk, clearing risk, country risk, and asset class risk.

10. By on-balance sheet and off-balance sheet: according to derivatives and non-derivatives.

11. Error account management.

12. By financial market categories: like wealth management business.

We can propose a sample book structure for presentation of account purpose on blockchain like this:

"m / accounting purpose' / currency type' / asset class' / financial product / dealer/transaction_index"/

The first level of book structure is the accounting purpose of trading and investment which compliance with IAS and IFRA. The second level is defined as currency type like USD, JPY, EUD and so on. The third level covers the functionality of asset management, and the fourth level handles financial product which includes forex, money market, fixed income, stock and derivatives.

Dealers group will be in the fifth level and the sixth level will contain transaction. This example shows how it work using hierarchical deterministic structure mapping into accounting book structure, and implement with triple entry ledger on blockchain.

3.2 Use Case: External and Internal Straight Through Processing with π Account

Blockchain network like bitcoin was built in a peer to peer environment. Addresses of transaction on blockchain protocol provide transaction linkage across entities. We notice that it also provides a triple ledger accounting system with π account to form both external and internal straight through processing program, to establish a hyper accounting platform.

In practice, the internal organization should establishes the hierarchical deterministic address/account, which mapping into the accounting book structure as demand. A multi-signature mechanism of transaction then could be implement to process the contract style with accounting period.

In the blockchain protocol, the multi-signature mechanism represents that the online or on-chain (called in blockchain) assets are managed by multiple individuals or entities. Moreover, trading an on-chain asset with an encrypted currency address, the owner of the address use his private key to sign to prove the ownership of the asset. Multi-signature scheme provides such control of assets using multiple private key signatures (Figure 8).

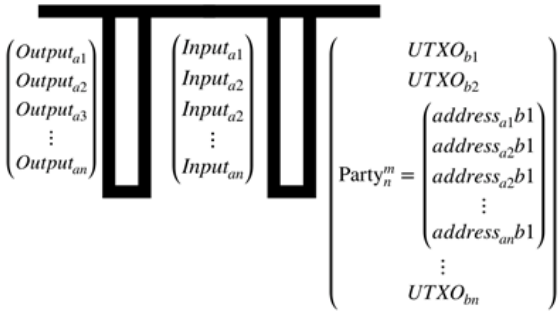


Figure 8. Multi-signature scheme

The figure shows that one or more of un-spend output scripts or UTXOs could be configured as M-N multi-signature scheme or address which embedded in transaction. One transaction involved n parties as set of (address1… address n), In a specific execution of multi-signature scheme, counter-party, accountant, trader, auditor, risk officer, regulator and any possible roles during transaction person could perform their duty very well. For example, two of three signatures are required to sign the transaction to valid state.

M-N multi-signature address with Straight Through Processing (STP) is used to complete asset allocation, classification, issuance, trading, settlement, audit, risk management, and accounting processing across multiple entities in the asset management process. Multi-signature confirmation address can be used by financial institutions and transactions in the asset management process The counter-party, accountant, and lawyer could separately confirm and sign the transaction using multi-signature mechanism on blockchain. The MN multi-signature address is deployed based on the term and condition of the contract on blockchain. According to the provisions of the contract, the contract execution scheme for generating the M-N multi-signature address, for example, must obtain more than half of the three signature confirmation addresses in the five signature addresses before the transaction can be considered valid.

In the practice of asset management, during the

execution of the asset allocation plan, in addition to the transaction confirmation by both parties to the transaction, the transaction confirmation signature can be performed through the signature of an external organization such as an accountant or a financial institution to speed up the process cycle. Transactions with straight through processing on blockchain network are processed in cross-entity organizations to ensure transaction compliance and reduce internal operational risks.

3.3 Discussion

Based on the research in this paper, we will develop a visual browser based on the data structure and flow of triple-entry accounting and π account, which can track the t relationship of transaction one by one. The picture shows the prototype of visual browser and we call it as "π or pi navigator" (Figure 9). In π navigator will contain transaction information includes set of input-address and set of output-address to provide index to link each other.

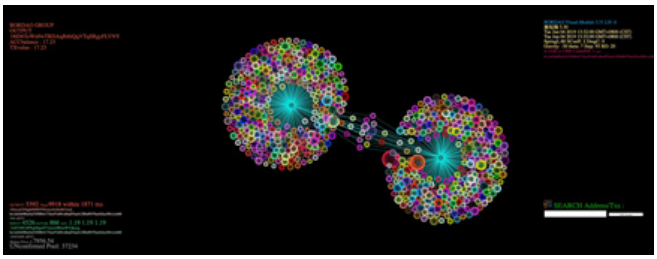


Figure 9. The prototype of visual browser

Macro Perspective: the Features of π navigator provides *incremental model* to collect transactions on specific block, or unconfirmed transaction pool to present whole picture of blockchain network. For example, the π navigator records real Bitcoin unconfirmed transaction on specific period (Figure 10).

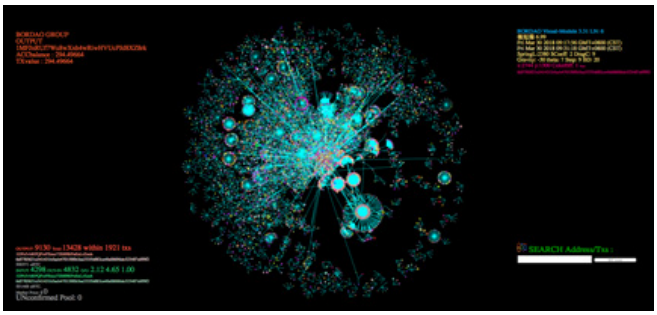


Figure 10. Real Bitcoin unconfirmed transaction on specific period.

Micro Perspective: the π navigator could observe each transaction in detail to check what input and output addresses includes, and then go for specific address to check one by one (Figure 11).

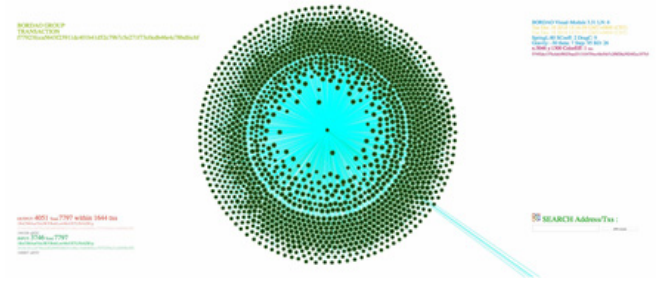


Figure 11. The detail of each transaction input and output addresses

Search Engine: The π navigator provides search engine to look for specific address or transaction and exam its behavior similar like AML or KYC from the bank. It will be easy to crack address and transaction association on blockchain, according to the graphical π navigator (Figure 12).

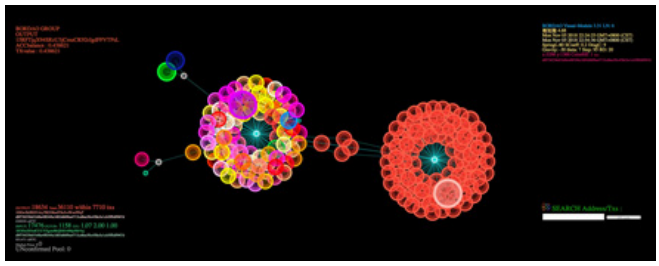


Figure 12. Crack address and transaction association on blockchain

Gravity model of Input-Output Pair: there is a theory in trading that volatility in trading volume are ahead of change in prices. Hence, in Bitcoin, we can observe both buy side and sell side by watching the deviation of input-output pair of unconfirmed pool incrementally, and perform great price prediction of bitcoin (Figure 13).

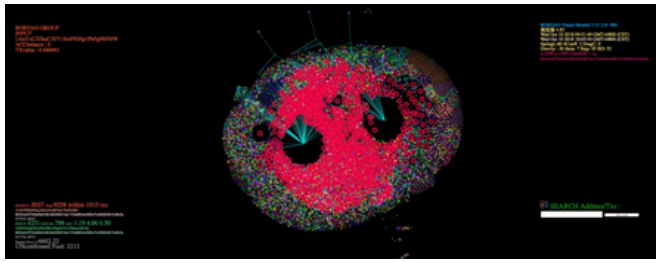


Figure 13. Bitcoin Prediction

Therefore, we can perform gravity of Input and Output to observe the strength of buy side and sell side, as picture shown, two black hole represent input and output respectively. We will continue to complete research of π account and blockchain technology and add new functions to pi account.

4 Conclusion

We perform new visual concept: π account, a scalable triple entry accounting system, based on the similar model like T-account with traditional double-entry accounting system. We also evaluate hierarchical deterministic structure on blockchain protocol to implement practical book structure mapping into accounting purpose. While this approach is s significant principle during accounting cycle. In addition, we conclude that both internal and external straight through processing could be implemented very well thought triple ledger accounting system on blockchain protocol. "Trading as settlement" model minimizes the operational risks of front to back office.

Overall, this paper makes three contributions. First, we outlines π-account with triple-entry accounting protocol, which has higher visibility, readability and higher efficiency than the T account while maintaining the existing bookkeeping system. Second, we introduces hierarchical deterministic structure to implement accounting book structure for commercial use. These book structure design are compliance with IFRS requirement and international accounting standard to ground the ongoing revolution over triple entry accounting system on blockchain infrastructure. Finally, we qualifies, through distributed ledger technology, triple entry accounting robustness and scalability.

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Biographies

Wang-Bor Chen is CEO of Bordao Co. He received his Master degree of Computer Science from Cornell University in 1993. He was the assistant professor in blockchain area at Tunghai University in 2019. He has served in large financial technology companies for more than 25 years, such as Uinsys, Sysware, Reuters, FNX, and Sungard. After that, he invested in the field of financial risk management and worked as a financial consultant for the Bank of Nanjing and China Postal Savings Bank in China. Now he has devoted himself to the research of blockchain, combined with finance and information technology, to develop a new blockchain infrastructure and distributed ledger Technology.

Ching-Tsorng Tsai is currently a professor of the Department of Computer Science of Tunghai University. He received the Teaching Innovation Award of Tunghai University in 2008, the Administrative Services Innovation Awards of Tunghai University in 2010 and 2012, the best paper award in Intelligent Living Technology Conference in 2005. Dr. Tsai received several grants on the research from the National Science Council of Taiwan and industrial application. He received the Ph.D. degree from the Department of Electrical Engineering, National Cheng-Kung University, Tainan, Taiwan, in 1994. Since 1994, he has published over 30 journal papers and over 100 conference papers, as well as participating in many academic activities, including serve as guest editor of Journal of computer (JOC) 2015, the conference chair of the 2012 and publicity chair on IEEE 2015 International Computers, Software & Applications Conference(COMPSAC 2015).

Jasper Tahnk is an Undergraduate Student at the University of Rochester majoring in Chemical Engineering. He has been heavily invested a lots of time in both Cryptocurrency and blockchain since high school. He has been helping Wang-Bor Chen in his endeavors developing further technologies like data collection and computer vision. Over 1500+ days of bitcoin blocks and transactions has been implemented into the prototype of visual browser, or π navigator.