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THE DEEP STRUCTURE OF AN ENNOVATTVE ACCOUNTING INFORMATION SYSTEM

C. Torben Thomsen
California State University, Fresno

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Department of Accountancy
California State University, Fresno

ABSTRACT

Once we have got a system we may proceed to taking it apart. First the tree, then the sawdust. And having attained the sawdust stage we should move on to the next, namely the building of further systems. And this for three reasons: because the world itself is systemic, because no idea can become fully clear unless it is embedded in some system or other, and because sawdust philosophy is rather boring. [Bunge 1977, p. v]

For centuries accounting was the only formal information system in existence for business enterprises. Now accounting is often only a small part of an integrated information system. While numerous attempts have been made to clarify the exact structure of accounting, they have all been encumbered by past traditions that, while optimal under manual methods, did not do justice to accounting in a database environment. This paper shows how an informal model of accounting as movement of sand in a sandbox can be mapped to an ontologically complete financial accounting information system. Finally, the new model is contrasted with three competing models, and its implications for design and use of accounting information systems are discussed.

1. INTRODUCTION

Accounting has the dubious distinction of having maintained its basic paradigm for one of the longest periods of any academic discipline. An examination of the first published work on double-entry bookkeeping (Pacioli 1494) reveals a marked similarity to present practice. Remarkably, this basic paradigm also survived the beginning of the computer age. Accounting was one of the first applications to be computerized. One would surmise that trained systems analysts together with thoughtful accountants could implement an optimized computerized system revealing the true elegance of the double-entry model.

Instead, the old manual techniques were merely computerized. One may hypothesize that this took place because accountants did not understand computers at the time, and/or systems analysts did not really grasp the basic structure of accounting and were therefore content to faithfully encode the past traditions as related to them by the accountants.

As an example, negative and positive numbers have never really replaced credits and debits in accounting. While there has been some debate over whether negative numbers were in use, when double-entry bookkeeping developed in the fifteenth century (see for example, Scorgie 1989 and Peters and Emery 1978), that debate is quite irrelevant, since it is unlikely that negative numbers would have been accepted in bookkeeping due to practical constraints. Since all arithmetic was done mentally, it was very efficient to separate negative numbers from positive numbers and process them together in different groups. Thus developed left for debit (+) and right for credit (-).

In today's computerized environment, where no human effort is involved in lengthy arithmetic processes, there is no compelling reason to avoid a mathematical sign by positioning numbers in different columns.

This paper seeks to construct a new paradigm that can serve as the basis for intelligent and efficient design of accounting information systems. The characteristics sought in such a new paradigm are simplicity, universality, and economy.

2. PROBLEMS WITH EXISTING SYSTEMS

Incompleteness. The basic financial statements were meant to give a *comprehensive* overview of a business enterprise. But they do not. According to Wand and Weber (1989) for a **decomposition** of a system "every element in the structure of the system is included in the structure of at least one of the subsystems in the set." The balance sheet, as one subsystem, includes **all** the stocks of the system. The income statement and the cash flow statement are another two subsystems that include **some** of the flows in the system. One of the chief omissions is capital purchases. The cash spent for capital purchases is reported in the cash flow statement, but actual capital purchases on an accrual basis are not reported anywhere.

Furthermore, even deriving a cash flow statement from an existing general ledger accounting system is a tedious process. There are no accounts reporting collections from customers or payments to creditors. Neither is it possible to determine directly from the ledger which of those payments are operating flows and which are investing flows.

Most existing accounting systems use a single ledger to record **all** stocks (balance sheet accounts) and **some** flows (revenues and expenses). The flow accounts are periodically closed into stock accounts. If accounting is to be viewed as a special case of a more general system for modeling closed systems, such glaring incompleteness is unacceptable. Sorter, Ingberman and Maximon (1990) are among the first to present a comprehensive coding scheme for all flows. However, their coding scheme was used not to design a new system but merely to explain the structure of existing systems.

Counter-intuitive Concepts. A requirement for good systems design is a clear conceptual schema. The foundation for present accounting systems is the equation

Assets = Liabilities + Equities

Using the analogy to a balance: an asset is a weight on the left pan, and a liability is a weight of the same mass on the right pan. Liabilities and equities, which have a basic **negative** nature are treated as **positive** quantities on the opposite side (pan) of the equation (balance) from assets. (In the new paradigm: an asset will be described by a hill in a sandbox, and a liability by a hole. This distinction between hills and holes is grasped far more intuitively and quickly than the distinction between left [debit] and right [credit].)

Obsolete and Narrow Terminology. The terms debit and credit are technical terms that have been widely misunderstood and have given outsiders the idea that accounting is something that is quite unique, rather than being a special application of something much more general and universally applicable. These terms can easily be replaced by terminology that is universally accessible and applicable, such as **to** and **from, plus** and **minus, in** and **out**.

3. STRUCTURE OF A NEW SYSTEM

There has been no shortage of proposals to elucidate, change, or formalize accounting. Among those are Mattessich (1957, 1964), Charnes and Cooper (1967), Sorter (1969), Sterling (1970), Ijiri (1975, 1986, 1988), Schrader, Malcom and Willingham (1988), and Koshimura (1988). Most prominent among the few studies that deal with accounting from the standpoint of information systems is McCarthy (1979, 1982), who based his analysis on the entity-relationship model of Chen (1976). McCarthy advocated that accounting be closely tied to and integrated with the overall management information system. A different approach that advocates isolating the accounting subsystem was explored by Tsing (1989). This approach is also taken here in the conviction that the salient features of accounting can best be understood in an isolated environment that exhibits only those features, i.e., the "deep" or fundamental structure of the discipline unencumbered by any unnecessary baggage.

Therefore the proposed model is **very limited**. {A fuller exposition of the model is made by Thomsen 1990, 1991.) The final end-products of accounting are dollar values assigned to various categories (first to **flows** and then indirectly to **stocks** by combining the summed flows). These values are usually arrived at in a market place by multiplying prices by quantities. All values are presumed to be parts of a supposedly homogeneous value set. No matter what the complexity or dimensionality of the events or transactions, they are translated into this homogeneous value set, which for ease of visualization can be thought of as the sand in a sandbox. The model can be expressed in numerous physical and mathematical ways, but the sandbox is the simplest and most intuitively appealing and will be used to illustrate the structure in the subsequent discussion.

The proposed model will also be **general** enough so that, with a suitable modification in terminology, it is capable of comprehensively modeling the flows of a uniform substance within any closed system. For simplicity of exposition, the model is very highly aggregated. But in practice it can be expanded hierarchically to any desired level of detail.

Finally, the proposed model will aim for **comprehensiveness**. The model should be able to fully account for all stocks and flows within the system. In fact, the accounting information system should be able to dynamically reconstruct any portion of the financial history of the enterprise.

In the light of the sandbox (see Figure 1), a business consists of **three** locations in the sandbox: **two** hills and **one** hole. One hill represents **goods** that are in the possession of the business, another hill represents **money**. (In this highly aggregated model, money includes not only cash but also receivables and payables.) The goods and the money belong to the **investors**, represented by a hole from which the sand in the goods and money locations came. That investor hole will eventually be filled up by the value (sand) now resident in the goods and money locations (hills).

These three locations (goods, money, and investors) are connected by means of five flows (pipelines) that transfer sand (value) **from** one location **to** another:

1. **Financing** supplies money from the investors to the business.

2. **Purchases** exchange money for goods.

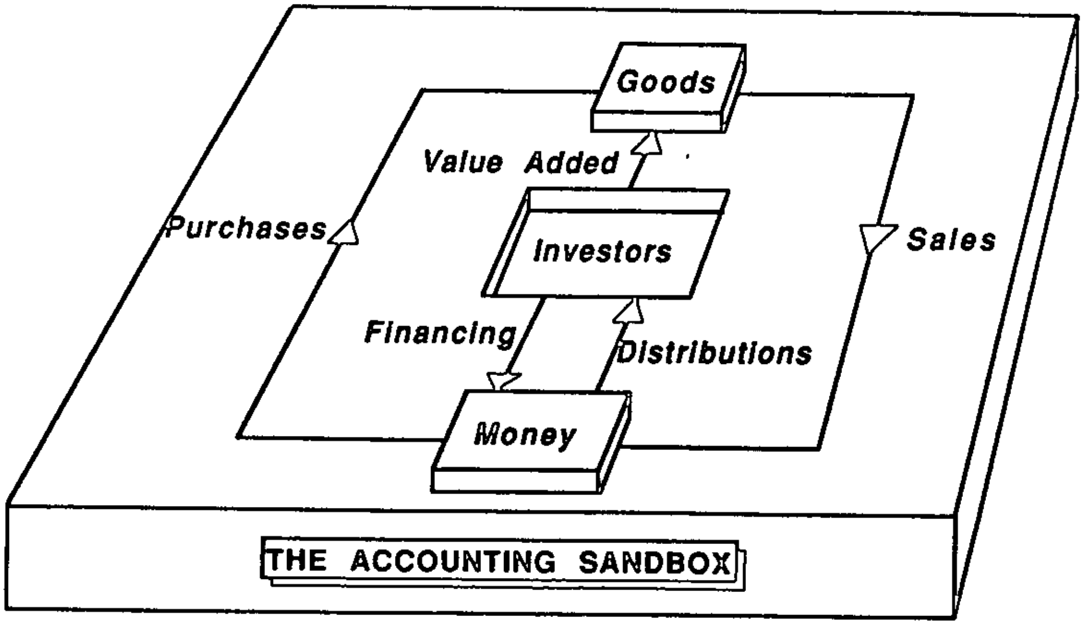

Figure 1. The Accounting Information System Modeled in a Sandbox

3. As the purchased goods are combined, their value is enhanced. The enhanced value comes from the investors. (The **value added** flow causes the investor hole to get bigger, i.e., the business owes the added value to the investors.)

4. The goods (products) are sold in exchange for money (**sales or revenue**).

5. Some of the money is returned to investors (in the form of interest and dividends) (**distributions**).

The accounting sandbox is capable of accommodating any degree of complexity or detail by the addition of more named locations and more named flows. By changing names and connections, it is possible to use the same model to describe the complete finances of IBM, the flow of electrons within a battery, the circulation of the blood, the CO_2 cycle in nature, or the flow of any uniform substance in a closed system.

What minimal record keeping will completely describe such a flow system? First, the system has a structure described by the named locations, to each of which is attached an initial condition giving its value at the start of the modeling process:

Named Location (stock)	Initial Condition (value)
Goods	0
Money	0
Investors	0

(The initial conditions all being zero refers to the sand being perfectly level in the sandbox at the beginning of play.)

Second, the connections between the various locations are described by a set of named flows **from** one location **to** another location:

Name of Flow	Definition of Flow FROM	TO
Financing	Investors	Money
Purchases	Money	Goods
Value added	Investors	Goods
Sales	Goods	Money
Distributions	Money	Investors

(Naming a flow together with an amount instructs the modeler to move a given quantity of sand **from** one location **to** another.)

Third, individual events are described by a triplet consisting of:

{Time, Flow, Value}

The **Time** gives the time of occurrence of the event using some standard clock. The **Flow** notes the name of the "pipeline" in which the flow is taking place. The **Value** is the dollar amount of the flow (or in the sandbox, the number of grains of sand that move). A sequence of such triplets is called a **journal**. Note that for each event much more information could be encoded. This is not done here because of the attempt to understand the essential minimal structure of the accounting information system.

At the end of the period or whenever an analysis is needed, the events in the journal are sequentially processed and summarized by the type of flow. The total value for each type of flow is **added** to the value of one location and **subtracted** from the value of another location. This summary process of **completely** describing events in the system and their effect is illustrated in Figure 2 using the highly aggregated data of IBM for 1989.

Note that this summary report of the accounting information system comprehensively shows **all** the flows that caused a beginning stock (initial condition) to change to its ending value. Also note that all lines in the model sum to zero, because the model represents a **closed system**. The general concept of a closed system replaces the traditional and more narrow equality of debits and credits.

		Location (Stock)			
		Money	Investors	Goods	Σ
	Ending Value	4.6	-55.9	51.3	0
	Initial Condition	8.4	-55.6	47.2	0
	Σ Flows	-3.8	-0.3	4.1	0
Value	**Flow**				
57.1	Purchases	-57.1		57.1	0
8.3	Value Added		-8.3	8.3	0
61.3	Revenue	61.3		-61.3	0
8.6	Distributions	-8.6	8.6		0
0.6	Financing	0.6	-0.6		0

Figure 2. Accounting Information System for IBM 1989 (Values in billions of dollars)

The sandbox again provides an appropriate analogy. At the start of playing, the initial level of the sand is arbitrarily labeled as 0. If in any location (stock) sand is above that level, it will be assigned a positive number, and if it is below, it will be assigned a negative number. Note that in the "accounting sandbox," assets will be "hills" and liabilities and equities will be "holes." Each flow affects two stocks in the opposite direction and therefore sums to zero. One location has sand taken away to be put in another location.

4. ONTOLOGICAL ANALYSIS

Wand and Weber (1990) developed a theory for the deep structure of information systems. They proposed a set of necessary ontological constructs for any representational model of information systems based largely on the work of Bunge (1977, 1979). The entity-relationship model, which in its REA embodiment by McCarthy (1982) is one of the most prominent proposals for structuring accounting information systems, was found to be seriously flawed in four different aspects when evaluated by their ontological model. Since the sandbox is a competitor to the REA model, it is important that it passes the test of ontological completeness. Table 1 carries out a brief analysis of the innovative accounting information system using the Wand and Weber (1990) ontological constructs.

No significant problems arise in the analysis, and the sandbox model is therefore ontologically complete. But there remains the tension between "thing" and "event." In Wand and Weber's model a "thing" is the elementary unit, whereas in the innovative accounting information system, the elementary unit is an "event." But this is the unresolved philosophical problem of what comes first: the chicken or the egg. In the new system, "things" come about as a result of "events," which are the only elements that are stored in the information system. But at the same time it is recognized that "events" are not possible without "things."

5. COMPARISON WITH EXISTING MODELS

Figure 3 graphically compares the sandbox with three competing models: the traditional double-entry model, the Ijiri (1989) wealth-income model, and the McCarthy (1982) REA model.

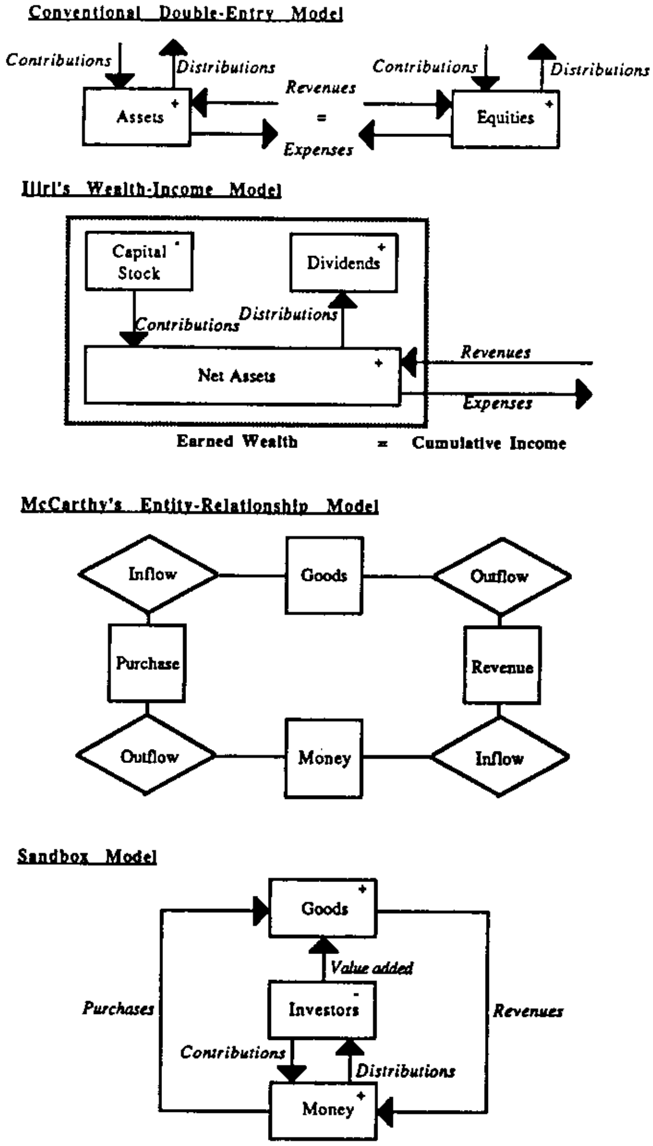

Figure 3. Comparison of Various Accounting Systems Models

Table 1. Evaluation of the New Accounting Model for Ontological Completeness

Thing	Things are equivalent to locations or stocks. They are goods, money, and investors. While some things have a direct relationship with the real world, others are defined as sums of events.
Properties	The only property of a thing is its monetary value.
State	The state of a thing recorded is its value at a point in time. Since the thing has only one property, its vector of values has only one element.
Conceivable State Space	The set of all positive and negative integers and zero. The smallest unit of value in the system is one (in the United States it is a penny).
State Law	In practice, goods are limited to the positive integers, investors usually occupy only the negative integers, while money may assume both positive and negative values. These limitations are due to conventions in the business world.
Lawful State Space	See discussion under State Law above.
Event	The aggregate model consists of five event pairs: financing, purchases, value added, sales, and distributions. Each pair increases one thing and decreases another thing.
Transition Law	Accounting conventions and practice define those events that are admissible to the system.
Lawful Event Space	All events that are deemed recordable according to generally accepted accounting principles.
History	The history of a thing is uniquely given by the sequence of events (positive and negative) that define it.
Coupling	The things are coupled by means of event pairs. A thing that is decreasing acts on another thing that in increasing by the same amount.
System	The three things are a system. Since each thing is coupled to at least one other thing, any two exhaustive subsets of things will have at least one coupling between them.
System Composition	The three things in the system are its composition.
Systems Environment	Events in the real world that cause (because of the rules of accounting) grains of sand to move.
System Structure	The following five couplings: (Investors, Money); (Money, Goods); (Investors, Goods); (Goods, Money); and (Money, Investors).
Subsystem	Any collection of things from the system together with their couplings will be a subsystem.
Level Structure	The highly aggregated systems does not have a level structure. But a level structure can easily be formed by defining an increasing level of detail.
External Event	All events in the accounting system are triggered by real world events.
Stable State	All things are in a stable state, because they will not change except because of an external event.
Unstable State	There are no unstable states.
Internal Event	Since all events are external events, there are no internal events.
Well-Defined Event	All events within the system are rigidly structured and therefore well-defined.
Poorly-Defined Event	There are no poorly-defined events within the system.

The deficiencies of the **traditional double-entry model** have already been noted. It is based on the equality of two stocks (assets and equities) and on the inequality of two flows (revenues and expenses). Note that each external flow must be recorded twice. For example, the issue of some shares of stock is recorded twice: once as an increase in the asset cash and once as an increase in the stockholders equity. The model, as anyone who teaches or has taken accounting knows, is abstract and redundant. Most importantly, it is incomplete. The revenues and expenses are recorded as special subdivisions of equities, but no other flows receive similar treatment, i.e., being incorporated as special flow accounts within the ledger. The traditional model might have been optimal given the absence of negative numbers and the tediousness of manual sorting and summarizing of records, but it should certainly not have been accepted blindly (as it was) when implemented on computer systems.

The **wealth-income model** of Ijiri (1989) was a laudable attempt to discover the underlying logic of double-entry and then extend it to higher dimensions. Instead of dealing with two kinds of stock accounts (assets and equities) Ijiri proposes to consolidate all the stock accounts into one category called "earned wealth." The basic accounting equation then becomes not an equality between two stocks but rather an equality of earned wealth and cumulative income:

$$\textbf{Earned Wealth} = \textbf{Cumulative Income}$$

or expressed in more general terms:

$$\Sigma \text{ Stocks} = \Sigma \text{ Flows}$$

Starting from this relationship between two dimensions, where income is the first derivative of earned wealth with respect to time, it becomes possible to extend the system to higher dimensions either by further integration or differentiation.

In contrast the sandbox represents a **closed** system in which

$$\Sigma \text{ Stocks} = 0$$

and

$$\Sigma \text{ Inflows} = \Sigma \text{ Outflows}$$

This system is not artificially configured to show "earned wealth." But it is possible to analyze the dynamics of any of the flows in the system using standard mathematical techniques. The basic question is whether the system should be configured to derive the dynamics of a certain set of flows, income flows (as Ijiri's model is), or if it should be constructed from a neutral point of view (as the sandbox is)?

Another problem with the Ijiri system is whether higher order derivatives are observable, derivable, or recordable. In a physical system, such as inertial navigation, the acceleration along the three axes (x, y, and z) are recorded directly by three accelerometers. Their readings over time are then integrated to find velocity (flow), which again is integrated to find location (stock). It is doubtful, except in very unusual circumstances, that the equivalent of "acceleration" can be directly and unambiguously observed and recorded in the business world.

McCarthy's (1987) REA (resources, events, agents) model, also explained in Armitage and McCarthy (1987), is based on the entity-relationship model, which was found to be ontologically incomplete by Wand and Weber (1990). Note in Figure 3 how entities are shown by squares and relationships by diamonds. For compactness, the diagram shows only a portion of the comparable model. Also note that both stocks and events are shown as entities. When a relational database is constructed using the diagrams, every stock entity will have one table and every flow entity will have three tables (one for the flow itself, one for the relation with the debit account, and one for the relation with the credit account). To duplicate the sandbox model, which has three states and five flows would therefore require 3 + 5 x 3 = 18 tables, which is, to say the least, cumbersome.

The most important feature of the **sandbox** is its being a closed system. This does not mean that it does not interact with the environment—the sandbox is driven by events in the environment—but rather that events within the system are constrained to occur in pairs: an increment in value coupled with an equal decrement in value. That type of very general model is of interest when one is concerned with a complete accounting for any set of phenomena, whether it be the atoms constituting a chemical reaction, the blood in the circulatory system, the path of a pollutant through the environment, the ripple effect of an apparently isolated economic event, or the creation and distribution of value by a business. For all of those phenomena, one could use a sandbox model with suitable labeling. The main appeal of the sandbox therefore is its generality and simplicity.

6. IMPLICATIONS FOR SYSTEMS DESIGN

Tentative Nature of the Ledger. The essential elements of a sandbox accounting information system are

1. a structure defining each type of value **flow from** one stock to another stock.
2. a history file consisting of triplets: {Date, Flow, Amount}.
3. a set of initial conditions (values) for the stocks.

Complete reports for any period can be obtained by processing these three files. If the processing facilities (electronic or manual) are relatively slow, the system design may be optimized by, at given intervals, inserting in the history file an updated set of cumulative initial conditions. To answer questions about the tenth year of a company's history it would be only be necessary to start with the cumulative initial conditions at the beginning of the tenth year and then sum the flows for the tenth year. But the question of how frequently to insert these cumulative initial conditions (equivalent to the ledger) is strictly dependent on the speed and cost of processing the flows.

The necessity for the ledger depends on the technology available for summarizing flows. If powerful enough technology is not available, one may use a ledger to spread the work of summarizing the journal throughout the period, but the ledger is not necessary from a logical standpoint.

User Interface Consistent with Conceptual Structure. Thomsen (1990, 1991) demonstrated how an abstract picture of the sandbox now called the *business instrument panel* can serve as a fast, practical, and powerful user interface with accounting data. When there is such a direct link between the conceptual structure and the visualization in a user interface, the designer's task is simplified and the ultimate user has an easier time communicating with the system's designers. Another interesting feature of the *business instrument panel* version of the sandbox is that, since it uses neither text or numbers, it can serve as a new international language of business. Paradoxically, it was the designers' attempt to produce a structure consistent with the existing manual user interface that led to some of the problems with existing accounting information systems.

Completeness. The sandbox design removes the most important weakness of existing accounting information systems: the inability to get complete information about all stocks and flows. With the sandbox system, it is conceptually possible to answer questions about the state of any stock variable at any point in time and about the size of any flow in the system for any period of time. The only practical problem is the "fineness" with which individual events are recorded. For example, will a depreciation flow be recorded daily, weekly, monthly, quarterly, or yearly?

7. CONCLUSION

The accounting information system that has been presented is so simple and yet so unique that it is best treated as a separate subsystem of the overall management information system. After the system has been structured, each event is recorded by a simple triplet. The creation of these "triplets" will be the responsibility of the management information system. Most of the challenging design tasks will be in structuring the interface between the management information system and the accounting information system and their linkages with the real world.

When one realizes that accounting is simply the moving of sand around in a sandbox, it is immediately apparent that such a model is severely limited in its ability to model the complex realities of the modern business world. While the sandbox is unequalled in expressing a compact representation of the entire business, and the sandbox is also a universally applicable tool to be thoroughly mastered by all business people, serious researchers will do well to turn their attention to modeling outside of the sandbox.

8. ACKNOWLEDGEMENTS

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