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Modeling Of Sokoto Cement Production Process Using Finite Automata: Compact Model

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Abstract: *Automata models are among the computational models used in design and construction of industrial processes. Deterministic finite automata are used for specific operation procedures involving known start and specific accepting and or end states. This paper adopts the method of the deterministic finite automata to construct the compact production model by using the production processes to denote different states linked by different transition functions. The preliminary results indicate that from the compact model of the cement production processes the transition table so obtained can be used to interpret the order of the cement production process and a gateway towards studying more detailed transition matrix in terms of algebraic theoretic properties.*
Key Words: *Finite State Machine, States, Automata and Transitions*

I. Introduction

The term 'finite automata' describes a class of models of computation that are characterized by having finite states. The use of the word 'automata' harks back to the early days of the subject in the 1950's when they were viewed as abstract models of real circuits (Lawson, 2005). A Finite State Machine (FSM) or Finite-State Automaton (plural: automata), or simply a State Machine, is a mathematical model computation used to design both computer programs and sequential logic circuits. It is conceived as an abstract machine that can be in one of a finite number of states. The machine is in only one state at a time; the state it is in at any given time is called the current state. It can change from one state to another when initiated by a triggering event or condition, called a transition. A particular finite state machine is defined by a list of its states, and the triggering condition for each transition (Wikipedia).

The behavior of state machines can be observed in many devices in modern society, which perform a predetermined sequence of actions depending on a sequence of events, they are presented with. Simple examples are vending machine which dispense products when the proper combination of coins are deposited, elevator which drop riders off at upper floors before going down, traffic lights which change sequence when cars are waiting, and combination locks which require the input of combination numbers in the proper order (Aho and Ullman, 1995).

Finite-state machines can model a large number of problems, among which are electric design automation, communication protocol design, language parsing and other engineering applications. In biology and artificial intelligence research, state machines or hierarchies of state machines have been used to describe neurological system and in linguistics to describe the grammars of natural languages. Considered as an abstract model of computation, the finite state machine is weak; it has less computational power than some other models of computation such as the Turing machine. That is, there are tasks, which FSM cannot do but a Turing machine can do. This is because the FSM has limited memory. However, finite automata have been used to model real life problem that have a finite process (Hopcroft, Motwani, and Ullman, 2001).

A typical production system is composed of multiple machines and workstations that perform various operations on a part of production, and a material handling system that interconnect these machines and workstations. Parts are processed to completion by transiting them through various machines and workstations according to their individual process plan. After processing is complete the parts leaves the system and proceeds to the next state until the final state of production is reached (Yalcin, Tai and Boucher, 2000).

For most manufacturing systems, operation runs sequentially reaching desirable or pre-specified states. For Example, a shop floor is normally controlled so that it produced a specific set of products. Each product goes through its own part of states until it reaches completion, i.e., the final state (Kim, Shin, Wysk and Rothrock, 2010).

The idea of using finite automata (FA) in modeling the production system of cement is strictly based on the fact that the system has finite states of production process with a finite link from a state to the other expressed in terms of machine sequence. A detailed approach to modeling a cement production process should include all stages of production and transitions from the raw material to the finished cement (Garcia-Diaz and

Lee, 1995). In particular, finite automata models have been used to model and develop a control for manufacturing systems (Kim, Shin, Wysk and Rothrock, 2010).

In cement production process, the state of machine changes after each instruction is executed, and each state is completely determined by the prior state and the input. The machine simply starts at an initial state, changes from state to state and reaches the final state (O'Castillo and Tapia, 1999).

This paper proposed to construct the compact model of finite automata of the Sokoto cement production process. It also seeks to study the models in terms of its algebraic theoretic properties, from which a transition table is formed with a clear relationship between the processes of production.

1.1 Cement Production Process

The process of cement production begins from the quarry where the major raw material (lime stone) is excavated. After geological test and survey has confirmed a particular piece of land containing limestone, the excavation process begins. The topmost part of the soil contains gravel and laterite, which are removed to properly see the limestone. Limestone can be categorized into two categories; the high grade and the low-grade limestone, the identification of these different grades of limestone can be noticed physically. The high grade is harder and brighter while the low grade is darker and softer. The required amount of calcium carbonate to be present in a limestone to make it a high grade is 80% upward while in low grade is 67%- 75%.

The limestone is further crushed separated to smaller particles that will ease the process of production and packed into piles stock. There are four piles stock where high grade limestone are packed in pile stock 1 and 2 with different concentration of calcium carbonate while the low grade limestone are packed in pile stock 3 and 4 also with different concentration of calcium carbonate. Here, the limestone in the pile stocks will be mix to get the targeted quality concentration of calcium carbonate of 74.5 – 75%. The quality target mix is done in raw mill, which is then stored in the silo. It is at this point the raw material is ready for the next stage of production, which is the clinker process. At this stage the raw material is passed into the cyclone where it is preheated(at 680^0C), the production further proceeds to the rotary kiln where the clinker (a grain like balls) is produced. After the production of clinker, it is passed into the cooler where it is cooled and ready for the next state of production process.

After the clinker is cooled it is further transferred to the cement mill where it takes another phase of production. The clinker is mixed with gypsum and other additives into the grinder to produce the powder, which is the required cement.

Although we have the required cement but that does not mean that it is the final state of production. The required cement is moved to the final state of packaging and storing which complete the cement production process (Quality Control Department, CCNN Sokoton. n.d.).

II. Method of Construction

In what follows, some notations are provided and the way they are used in the derivation process of the desired theoretic models are also explained.

2.1 Finite Automata

The proposed model type is the Deterministic Finite Automata, which is ruled, based on recursive action or machine. The term finite comes from the number of states and the number of inputs being finite; automation is from the structure or machine, deterministic since it cannot be in more than one state at a time (Lawson, 2005).

A Deterministic Finite Automata (DFA) consists of:

* A finite set of states (often called Q)
* A finite set $\sum$ of symbols
* A transition that takes argument of a state and a symbol and returns a state (often denote δ)
* A start state often denoted q_O
* A set of final or accepting states (often denoted F)

So a Deterministic Finite Automaton is mathematically represented as a 5-tuple $(Q, \sum, q_0, \delta, F)$and define thus:

Let Q be a finite set and let $\sum$ be a finite set of symbols. Also letδ be a function from $Q \times \sum \rightarrow Q$
Let $q_0$be the initial state in Q and let F be a subset of$Q$.
We call elements of Q states, δ the transition function,$q_0$the initial state and F the set of final state(s).

2.2 Development of a Compact Model of Finite Automata for a Cement Production Process

A compact model is derived using some underlying theoretic schemes and based upon the assumptions of deterministic finite automata.

Consider the following:

Basically, there are four important states in cement production processes: the raw material state, the clinker process state, the cement mill state and the finished cement state.

Let us denote as follows:

q_0 = the raw, material state
q_1 = the clinker process state
q_2 = the cement mill state
q_3 = the finished cement

So $Q = (q_0, q_1, q_2, q_3)$ (1)

$\sum = (t_1, t_2, t_3, t_*)$ (2)

t_1 = process to second state of production
t_2 = process to third state of production
t_3= process of final state of production
t_* = no link for production process

Also

$\delta: Q \times \sum \rightarrow Q,$ (3)

Defines the transition function such that, $\delta(q_0, t_1) = q_1$

$\delta(q_1, t_2) = q_2$

$\delta(q_2, t_3) = q_3$

Other possible functions are $t_* F = \{q_3\}$

Based on (1) through (3) the following construction can be achieved

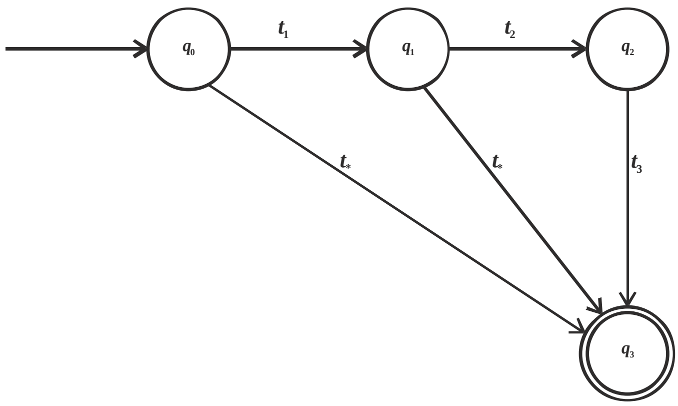

Fig. 1: A Compact Automata Model for cement production process

From the constructed model, a transition table can be formed for clearer picture of the theoretic algebraic properties of our finite automata model.

Table 1: Transition Table

States	q_0	q_1	q_2	q_3
q_0	1	t_1	t_*	t_*
q_1	.	1	t_2	t_*
q_2	.	.	1	t_3
q_3	.	.	.	1

III. Interpretation

From table 1 above, it can be seen that, the upper diagonal elements are non-zero, indicating a one way directional process of production. Also, by having 1s in the diagonal elements indicates a completion of the previous process before the next.

3.1 Conclusion

There is the need for the details of each of these production stages to be considered in order to see clearly the behavior of the detailed transition table with a view to having a transition matrix that contained the values of the non-zero elements for the sake of optimality test for diagnostic and remedial purpose.

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