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Dynamic Modeling of a Futuristic Frame-Based Knowledge Representation Using Unified Modeling Language (UML): A Case of an Intelligent Drug Marketers Tracking System (IDMTS)

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Authors' contributions

This work was carried out in collaboration between all authors. Author IES designed the study, structure the abstract, wrote the first draft of the manuscript and handled the software modeling and design. Author AOO managed literature searches. Authors BIE and WAA both managed the drug matter. All authors read and approved the final manuscript.

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ABSTRACT

Adulterated and counterfeit drugs are problems in Nigeria. Over 150 children died in 1989 as a result of paracetamol syrop containing diethylene glycol. This was so severe that neighbouring countries like Ghana and Sierra Leone officially banned the sale of drugs, foods and beverages made in Nigeria. The aim of this paper is to model dynamically, an innovative Frame-Based Knowledge Representation of an Intelligent Drugs Marketers Tracking System (IDMTS), that would aid the National Agency for Food & Drug Administration and Control (NAFDAC), and the National Drug Law Enforcement Agency (NDLEA) in the tracking of the trade names and locations of the makers and marketers of all drugs sold. The objective is to unravel the robustness and innovativeness of the rare combination of Frame and UML in knowledge representation and

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modeling. Generalization, Aggregation, Association and Classification are adopted as data abstraction mechanisms for the modeling of Classes to produce the hierarchies of objects in the "Purchasing of Drugs" frame. The UML (Unified Modeling Language), in the other hand, modeled the relationship among classes; actors, the generalization relationship between actors, and the association relationships between actor and use cases in the IDMTS. The UML is used due to its flexibility.

Keywords: Frame; UML; knowledge representation; drug.

1. INTRODUCTION

With increasing rate in fake, adulterated and counterfeit drugs problems in Nigeria, it is expedient to design an innovative knowledge based Intelligence system that will assist the supervising agencies of drugs and food administration in Nigeria in the tracking of the trade names and locations of the makers of all drugs sold.

Knowledge Representation *(KR) has long been considered one of the* principal elements of Artificial Intelligence, and a critical part of all problems solving [1]. Knowledge representation plays a vital role in AI, because how information is encoded determines what kind of reasoning can be done with the knowledge base, how complex it is and how much storage capacity is needed for the information [2]. Any mechanically symbolized intelligence process will be consisted of structural ingredients that; we as external observers naturally take to represent a propositional account of the knowledge that the overall process exhibits, and independent of such external semantically attribution, play a formal but fundamental and essential role in stimulating the behavior that manifests that knowledge [3].

How humans actually think and model the world is relevant to the design of programming languages and has always played a role in the development of new languages [4]. The effective representation of domain knowledge is therefore generally considered to be the keystone to the success of Artificial Intelligence (AI) programs [5]. The concept of a *frame* was proposed in the 1970's [6], and frame systems subsequently gained ground as basic tools for representing knowledge [7]. The fundamental idea of a frame system is rather simple: A frame represents an object or a concept. Attached to the frame is a collection of attributes (slots), potentially filled initially with values. When a frame is being used the values of slots can be altered to make the frame correspond to the particular situation at hand [8].

2. GLOBAL DRUG PROBLEMS AND REGULATION

In the United State, under the Food and Drug Administration, Safety and Innovative Act (FDAIA) of 2012, both domestic and foreign facilities whose products are imported into the US are required to register with the Food and Drug Administration (FDA) [9]. This requirement also applies to every person who owns and operates any establishment within any foreign country engaged in the manufacture, preparation, propagation, compounding, or processing of a drug or device that is imported or offered for import into the US states, (FDASIA section 702). The tracking itself will take place using an FDA established system known as Unique facilities Identification (UFI) system, which will allowed drug manufacturing facilities and owners to register with the Agency.

In Nigeria, NAFDAC is the government agency under the Federal Ministry of Health that is responsible for regulating and controlling the manufacture, importation, exportation, advertisement, distribution, sales and the use of food drugs, chemical and packaged water. The Agency was formed to checkmate illicit and counterfeit products in Nigeria in 1993 under the country's health and safety law [10].

Adulterated and counterfeit drugs are problem in Nigeria. Over 150 children died in 1989 as a result of paracetamol syrop containing diethylene glycol [11]. This was so severe that neighbouring countries like Ghana and Sierra Leone officially banned the sale of drugs, foods and beverages made in Nigeria.

3. KNOWLEDGE REPRESENTATION METHODOLOGY

Knowledge representation is an aspect of Artificial Intelligence (AI) which investigates how knowledge is being organized and processed, what kind of data structures an intelligent agent uses; and what kind of reasoning can and cannot be done with the knowledge. Any problem solving task presupposes some sort of a knowledge representation. The psychologically interesting question is to find out what type or types of knowledge representations the mind uses [4].

Knowledge representation has a critical role to play in AI, reason being that it determines to a very large extent what kind of reasoning can be done with the knowledge, how fast it is, how much memory is consumed and how best and complete the algorithms that make use of the knowledge are.

In order for a knowledge system to use domain specific knowledge, it must have a language for representing that knowledge. The basic criteria for a knowledge representation language according to [12] are the following:

- Expressive power - Can experts communicate their knowledge effectively to the system?
- Understandability - Can experts understand what the system knows?
- Accessibility - Can the system use the information it has been given?

This implies that, Knowledge Representation language must unambiguously represent any interpretation of a sentence (logical adequacy), have a method for translating from natural language to that representation, and must be usable for reasoning [13]. Wood's definition is simply a generalization of the Knowledge Representation Hypothesis where reasoning is the only scheme of "stimulating the behavior that manifests that knowledge." Reasoning is essential to Knowledge Representation, and especially to Knowledge Representation languages. Before knowledge can be represented adequately, it has to be broken down into its atomic components as conceptualized in Fig. 1.

There are basically three methodologies that are generally used, though optional, for representing knowledge. These methodologies/ techniques include.

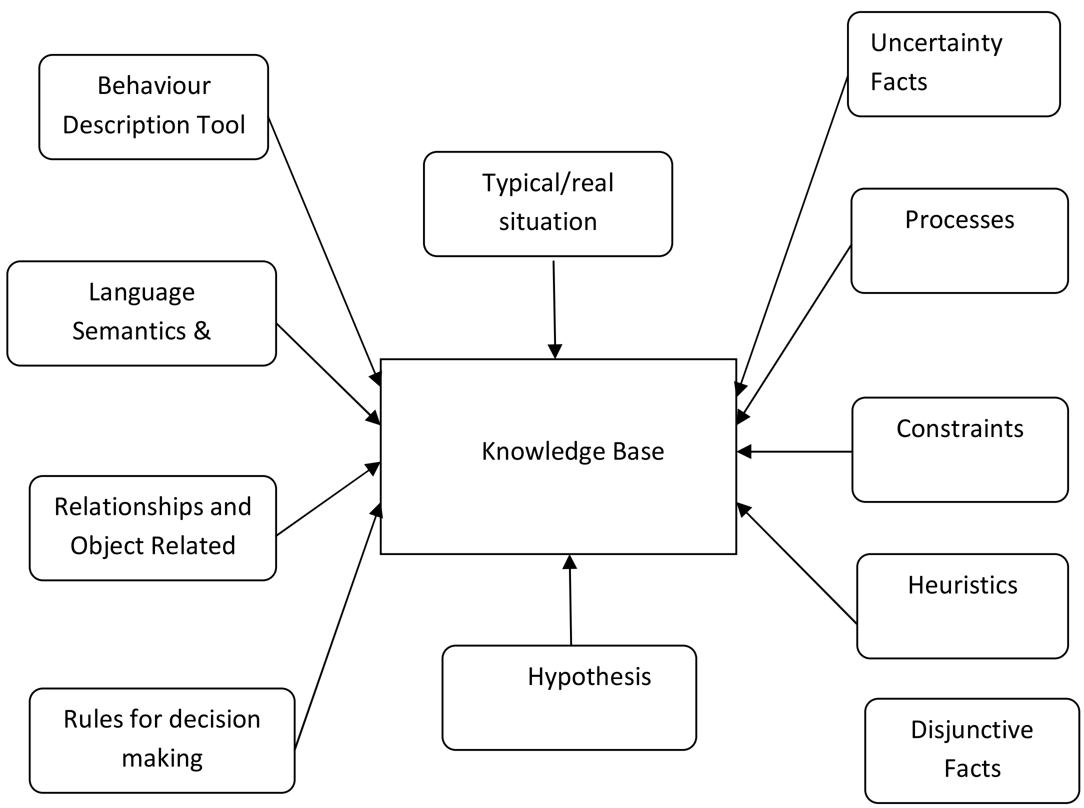

Fig. 1. Atomic components of knowledge

3.1 Predicate Logic

Predicates are functions of zero or more variables that return Boolean values. Thus predicates can be true sometimes and false sometimes, depending on the values of their arguments. Variables are symbols capable of taking on any constant as value. Predicate logic, also known as Predicate Calculus or First Order Logic gives the underpinnings to the languages of logic programming, such as Prolog. A predicate name, followed by an argument list in parentheses is called an atomic formula. The atomic formulas can be combined by logical connectives like propositions. For instance, if ***Reg(Tom)*** and ***Dep(Tom)*** are two atomic formulas, expressing that Tom Registered and that Tom has a Department respectively, one can form

$$Reg(Tom) \rightarrow Dep(Tom).$$

Predicate logic as an analysis tool is centered on the use of inference mechanisms to tell which inference one is bound to draw with respect to some rules. A typical representation of knowledge using predicate logic is in the declarative sense as demonstrated below:

Entity(Goat)
Entity(Dog)
Entity(Chicken)

For all X[entity(X) ---➜ Domestic animal (X)]

3.2 Production Rules

Production systems [7] are a form of knowledge representation where the knowledge is represented in a list of rules. Rules are encoded in a set of **if-then** clauses. The rules contain conditions and actions that fire if the conditions are satisfied. Basically, a production rule can be represented in general terms as:

$$\textbf{IF } A_1 \& A_2 \& A_3, \ldots, A_n$$
$$\textbf{THEN } B_1 \& B_2 \& B_3, \ldots, B_m$$

Where [A_i | **i = 1 to n**] are logical propositions or premises or statements consisting of a carefully considered opinion or judgment and having a Truth value of T(true) or F(false), and where [B_i | **i = 1 to m**] represents corresponding actions. This can be interpreted thus:

If the premise/proposition A_1 through **n** are all true **then** carry out action B_1 through **m.** A case material can be presented as follows:

IF (*Student has admission letter****) &***
(*Student pay acceptance fee****) &***
(*Student pay fee and departmental due****) &***
(*Student is screened****) &***
(*Student gets registration number*
THEN (*Student is eligible to Matriculate****) &***
(*Student in entitle to accommodation).*

3.3 Frame

A frame is another technique for knowledge representation. A frame is a data structure with typical knowledge about a particular object or concept [14]. A frame has two different types of name.

Every frame has a single *true name* (tname), which is a symbol referring, uniquely to that frame. In Lisp implementation, the tname is the Lisp symbol on whose property list the frame structure is stored. A frame can also have any number of *public names* (pnames), which are strings, and need not be uniquely referring. Public names are stored as values in the name slot of the frame.

Each frame has its own name and a set of attributes associated with it. *Name*, *Department*, *Faculty*, *Reg_Number and Year_of_Study* are slots in the frame *Student*. *Department, Rank*, Date_of_Employment, Date_of_Retirement and *Faculty* are slots in the frame *Lecturer*. Each attribute or slot has a value attached to it. Frames provide a natural way for the structured and concise representation of knowledge.

4. FRAME-BASED KNOWLEDGE REPRESENTATION TECHNIQUE

The concept of a frame is defined by a collection of slots. Each slot explains a particular attribute or operation of the frame. Slots are used to store values. A slot may contain a default value or a pointer to another frame, a set of rules or procedure by which the slot value is obtained.

In a Frame, s Slot contains the following information; Frame name, the Relationship of the frame to the other frames. The frame *Location* could be a member of the class *Purchaser*, which moreover could belong to the class *Manufacturer*. Also, a slot contains a Slot value. A slot value can be symbolic, numeric or Boolean. For example, the slot *Name* has symbolic values, and the slot *Age* numeric values. Frame-based intelligence systems provide an extension to the slot-value structure through the application of *facets*. A facet is a means of providing extended knowledge about an attribute of a frame. Facets are used to establish the attribute value, control end-user queries, and tell the inference engine how to process the attribute.

4.1 Frame Representation of the IDMTS

In this section, we modeled classes of object of the IDMTS which are related to one another using data abstraction mechanisms such as aggregation, generalization and semantic network. The Aggregation hierarchy, the Generalization hierarchy, and the semantic Network of the Aggregation and Generalization hierarchies are represented as depicted in Figs. 2 – 4. The frame with a parent node, "Purchasing of Drugs" with a special slot, "Item Purchase" is represented in the Aggregation hierarchy below.

4.2 Class and Instances of the Drug Frame

A *class-frame* describes a group of objects with common attributes. For example, Drug, Animal, *person*, *car* and *computer* are all class-frames. Each frame "knows" its class. We used the *instance-frame* when referring to a particular object, and the *class-frame* when referring to a group of similar objects. Frame-based systems support *class inheritance*. The fundamental idea of inheritance is that attributes of the class-frame represent things that are *typically* true for all objects in the class. However, slots in the instance-frames can be filled with actual data uniquely specified for each instance [1].

Drug class	
Class:	**Purchasing of drugs**
[str]	Drug Item Purchase
[str]	Major Supplier:
[str]	Owners' Identity:
[str]	Cost:
[str]	Maker/Manufacturer:
[str]	Manufacture Date:
[str]	Shop/Pharmacy
[str]	Name:
[str]	NAFDAC Reg. No.:
[str]	Trade Name:
[str]	Location:
[str]	Purchaser:

Drug inheritance		
Inheritane: Drug Item purchased		
[str]	Cost:	$ 2,000000
[str]	Maker/Manufacturer:	ELGON Group
[str]	NAFDAC Reg.No:	3667689
[str]	Medicines:	Maloxin
[str]	Stimulants:	Amphetamine
[str]	Depressants:	Morphine
[str]	Barbiturates:	Mandragora
[str]	Hallucinogens:	Mescaline

Drug inheritance	
Inheritane: Manufacturer	
[str]	Trade Name:
[str]	Location:
[str]	Owners' Identity:
[str]	Cost:
[str]	Company Reg.No:
[str]	Established Date:
[str]	Shop/Pharmacy:
[str]	TIN:

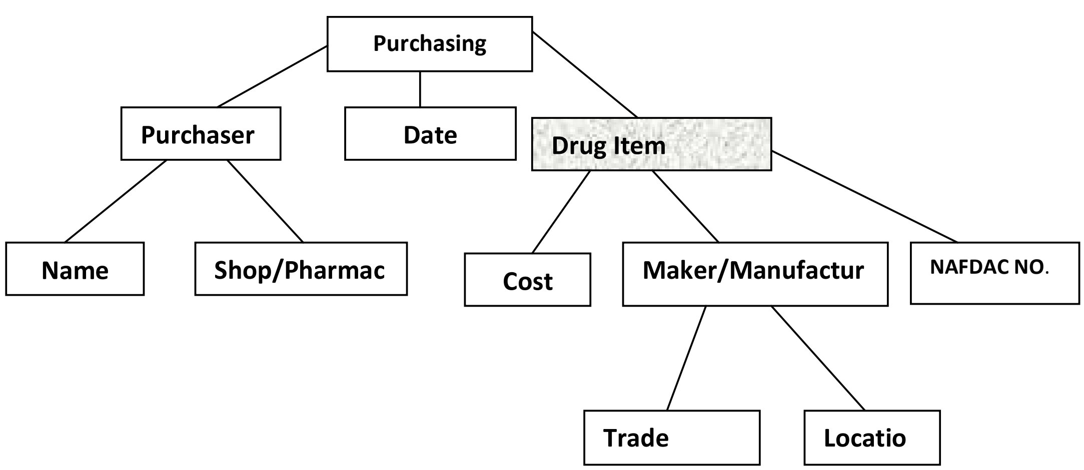

Fig. 2. Aggregation hierarchy for purchasing of drugs

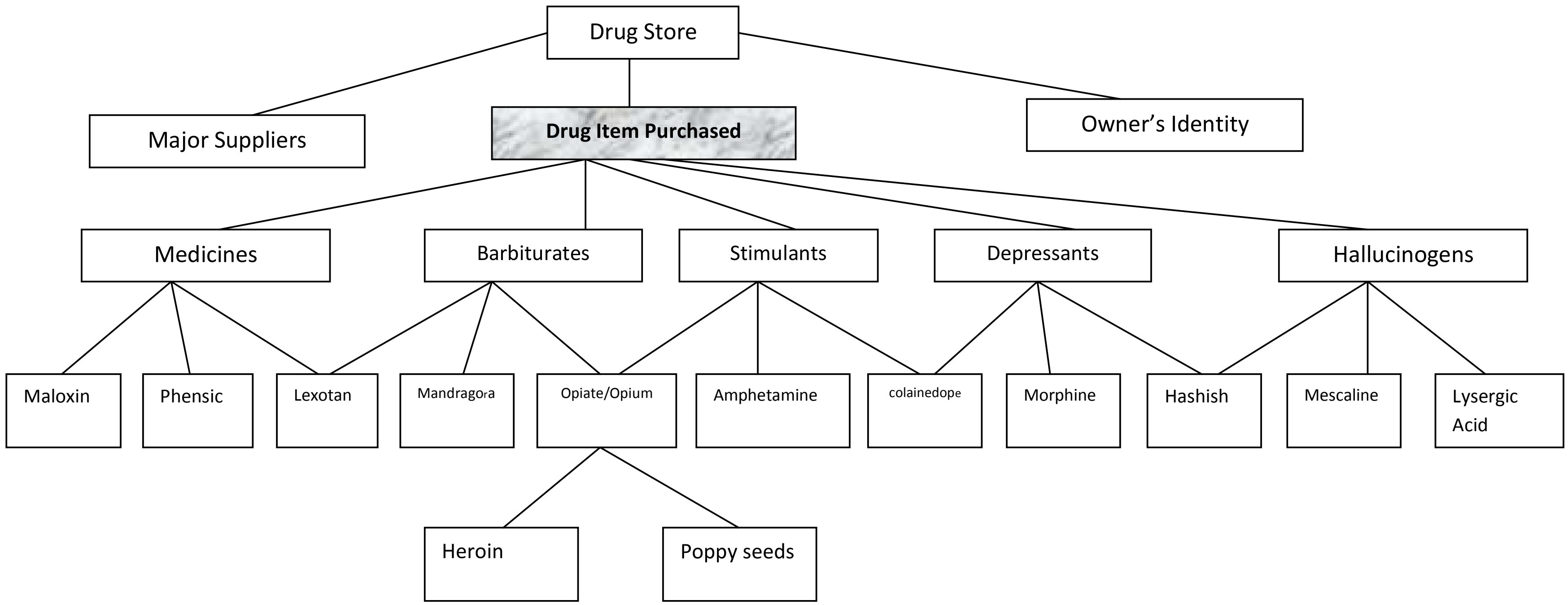

Fig. 3. Generalization hierarchy of drug items purchased

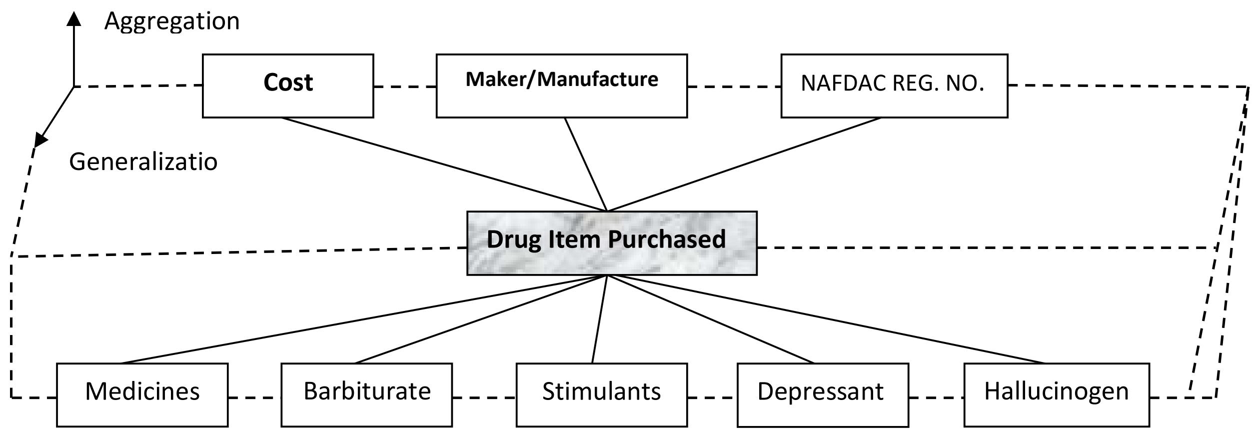

Fig. 4. Semantic network of generalization and aggregation hierarchies

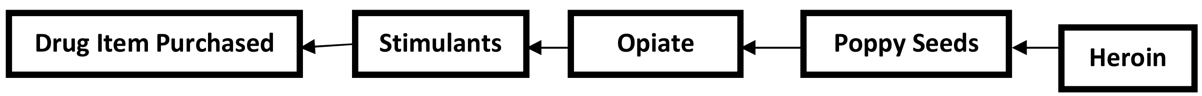

Fig. 5. Relationships of drug frames

5. SOFTWARE MODELING AND DESIGN WITH UNIFIED MODELING LANGUAGE (UML)

5.1 Use Case Diagram

A *use case* specifies the behavior of a system or a part of a system, and is a description of a set of sequences of actions, including variants, that a system performs to yield an observable result of value to an actor. An *actor* is an idealization of an external person, process, or thing interacting with a system, subsystem, or class. An actor characterizes the interactions that outside users may have with the system (*Rumbaugh, 99*). The *Drug manufacturer* interaction with the NAFDAC *Registrar* and the *NAFDAC Drug Register System* through a “*Register Drugs*” use case, and the full Use Case diagram for the IDMTS are shown in Figs. 5 & 6 respectively.

5.2 State Machine

The state machine here describes the dynamic behavior of objects in the system by modeling the lifecycles of objects of each class in the system. Each object is treated as an isolated entity that communicates with the rest of the world by detecting events and responding to them. The state machine for the IDMTS is shown in Fig. 7.

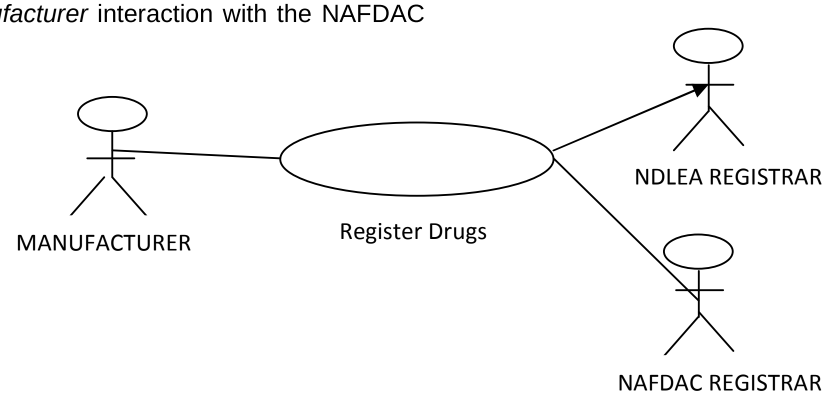

Fig. 6. *Drug manufacturer* interacting with the NAFDAC *registrar* and the *NAFDAC drug register system* through a “*Register Drugs*” use case

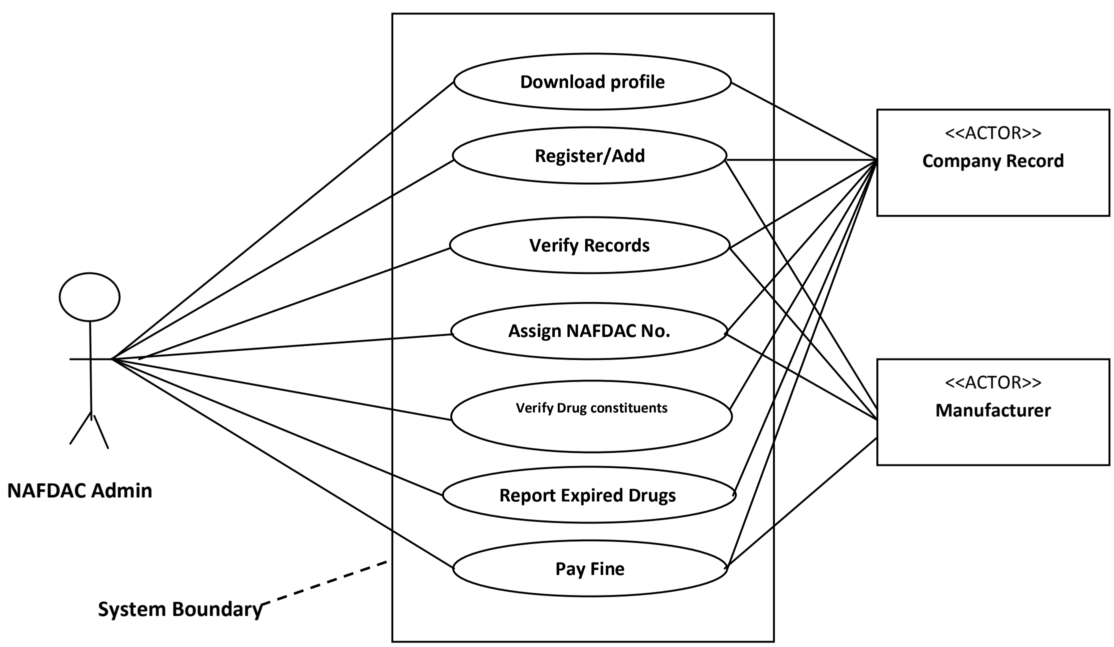

Fig. 7. Full use case diagram for the IDMTS

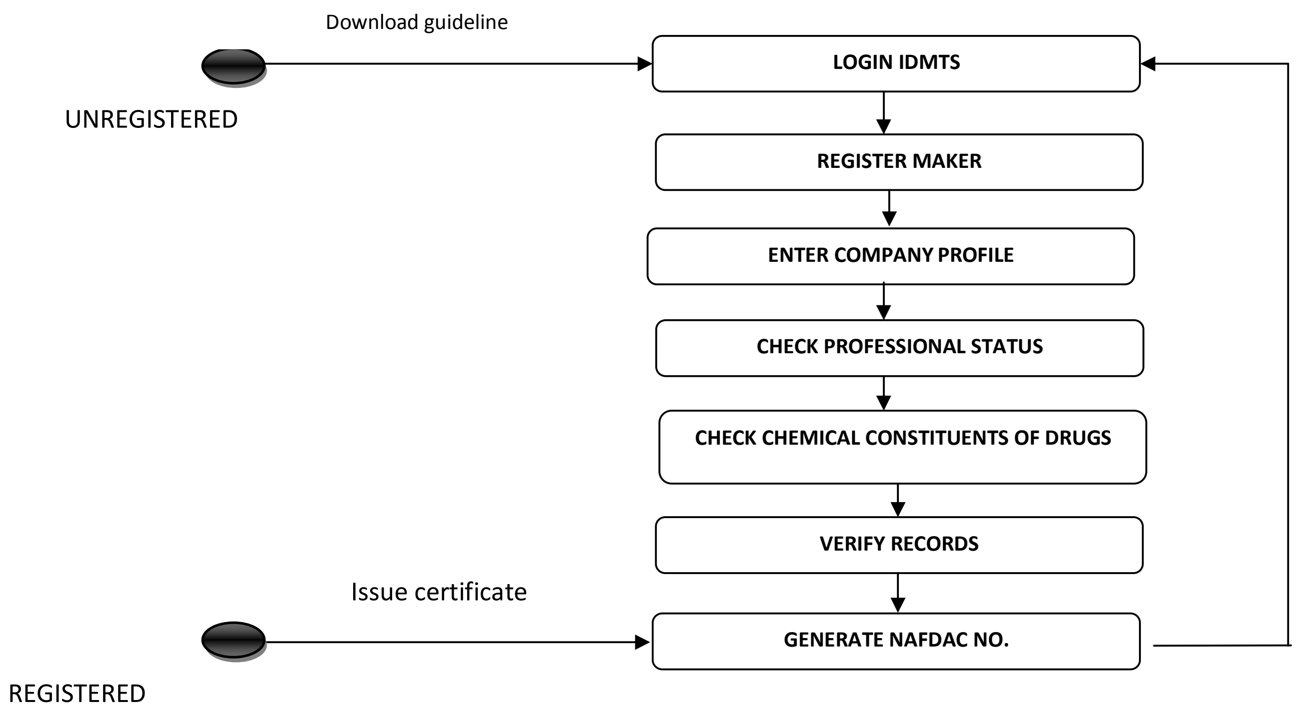

Fig. 8. State machine of the IDMTS

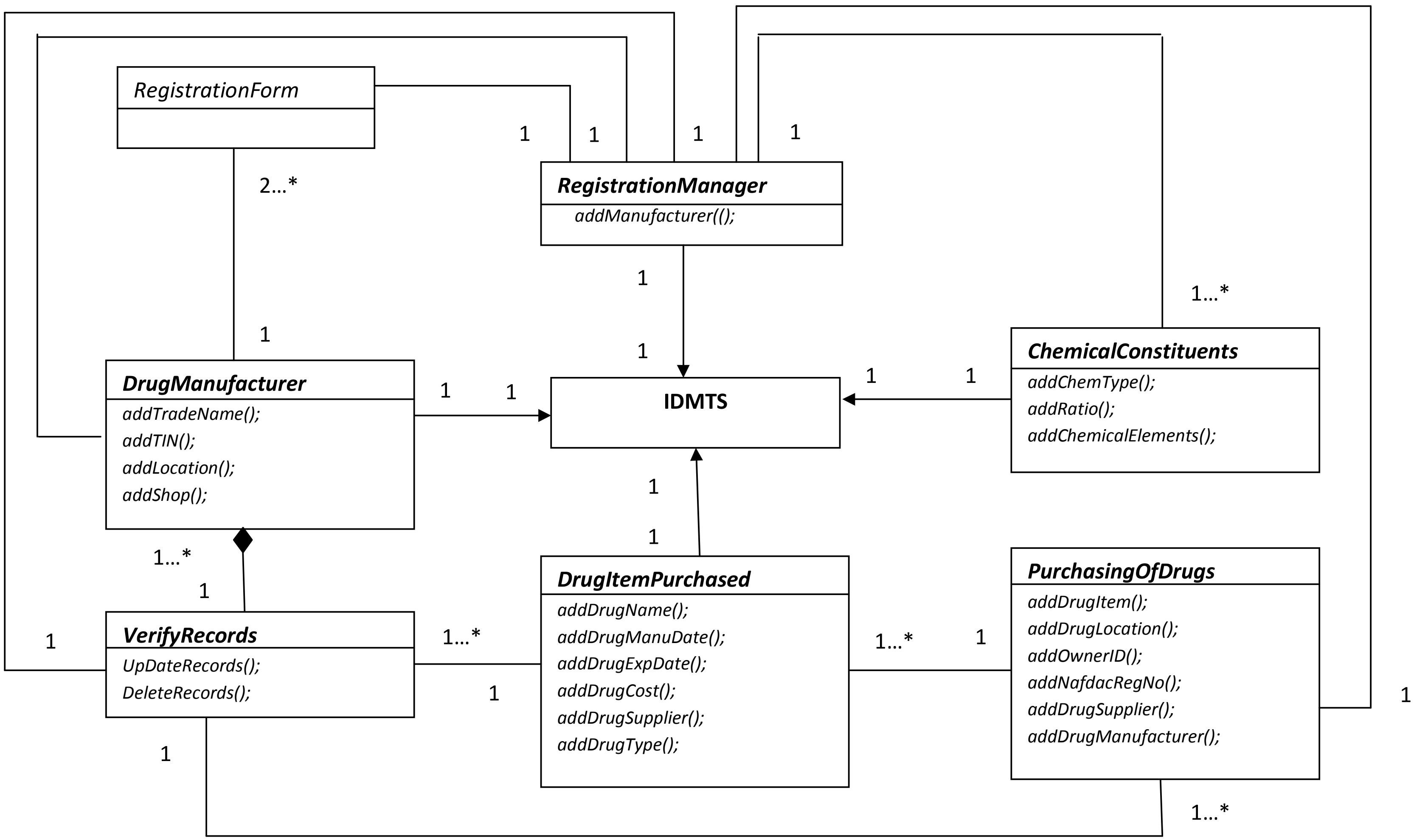

Fig. 9. Class diagram of class diagram of IDMTS

5.3 Class Diagram of IDMTS

A class is a collection of objects with common structure, common behavior, common relationships and common semantics. The classes required to build the package 'IDMTS' are identified and would be implemented using any language of preference. These classes are *Registration Form*, *Registration Manager*, *Purchasing of Drugs*, C*hemical Constituents of Drug*, *Drug Purchased, Drug Item Purchased*, Drug *Manufacturer* and *Verify Record* classes. These classes and their relationships are described in the UML Class diagram as shown in Fig. 8. The multiplicity values 0…*, 1…*, and 2…* indicates that 0, 1, 2 or more objects in a Class take part in the association between it and the class it is linked to.

6. CONCLUSION

This research work, which was borne out of the passionate concern of the authors over the incidences of fake, adulterated and counterfeit drugs harms in Nigeria, modeled a frame-base knowledge representation using UML as a tool. The paper has been able to unravel the robustness and innovativeness of the unusual combination of Frame and UML in knowledge representation when designing an Artificial intelligence based system. The lifecycles of objects of each class in the system have been modeled using a state machine to describe their behavior. The classes required to build the package have also been identified and their common relationships, behavior and semantics shown using a class diagram. It is believe that this paper will serve as a springboard for further research and is opened for the actual development, implementation and deployment of the expert application by any interested researcher(s).

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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