Patterns for African smart cities semantic data integration

Ferdinand Guinko
Institut Burkinabè des Arts et Métiers, Université Joseph KI-ZERBO, Ouagadougou, Burkina Faso

Abstract- Smart communities and cities is a topic widely presented in the scientific litterature. Numerous works have been done presenting the concept of smart city. But there is still a need concerning the matter of data integration in smart communities and cities. In this paper, we have presented the Users application layer pattern, the Integration middleware layer pattern, and the Data source layer pattern for data integration in smart cities.

Keywords - African Communities and cities, semantic data integration, Semantic interoperability, data exchange, Africa Smart communities and cities patterns

I. Introduction

A considerable body of research has been produced regarding African smart cities. We briefly present a few of them.

A. What we understand by the concept of pattern

The concept of pattern originates from the field of architecture [1, 3] and was introduced by architect Christopher Alexander in his book titled *The timeless way of building*. According to Christopher Alexander, a pattern describes a recurring problem in our environment, and describes the solution of this problem so that this solution is reusable as many times as desired [6].

Regardless of the field, the pattern concept is used to capitalize on the experience of the most experienced experts for the benefit of the less experienced. It allows in both cases to propose reusable solutions to recurring problems. Today pattern is widely used in many field of knowledge such as in pedagogical engineering, in mathematics, in computer science, etc.

A pattern format corresponds to a norm of description of the patterns. Several pattern formats exist. The most popular are on the one hand the *Alexandrian* format already presented in [8] which derives directly from the theory formulated by Christopher Alexander on the concept of pattern and on the other hand the format that has been proposed by the *Gang of Four* also presented in [9]. We will use a format resulting of a combination of the textual representation or description, and the graphical representation of patterns presented also in in [10]. The pattern description format is to be distinguished from the pattern itself.

Now that we have been introduced to the *pattern* concept, let us look, in the next section, at the current literature to see how patterns are used regarding smart city.

B. The pattern and the smart communities and cities concepts in litterature

At first the pattern concept is found in papers regarding urbanization in smart cities such as in [18] where Lifeng Shi and al. were able to show significant regional differences and patterns between coastal and inland areas and emphasize the fast and dynamic urbanization in coastal areas or in [2] were authors proposed an amenity-based sorting model for cities in England and found that there are important differences between cities in England.

Lot of work regarding patterns, smart city as a system of systems or smart city data, are also referenced in the literature. In [20] authors have proposed a concept to explore access models in the space-time domain for space-time data in a smart city. In [15] authors have proposed a solution to extract patterns of electric power consumption in time series from big data, so that very valuable conclusions can be drawn for managers and governments while in [5] energy use models for smart meter data within a specific timeframe that characterizes the behavior of energy consumers is rather based on an association pattern of association exploration rule and association technique based on rules of consumption habits according to days, weekends and weekdays. In a more global way, Gonzalez in [7] has identified existing business models patterns and has created a taxonomy of those patterns consisting of 12 groups and 61 assigned business model patterns.

In [4] authors, trying to answer the question *What are the ontological design models used in smart urban ontologies?* By studying the available smart urban ontologies, proposed a list of seven ontological design models. These design model ontologies help define basic concepts to guide the development of smart city ontologies. For example, figure 1 represent an example of pattern, the pattern named *City object*.

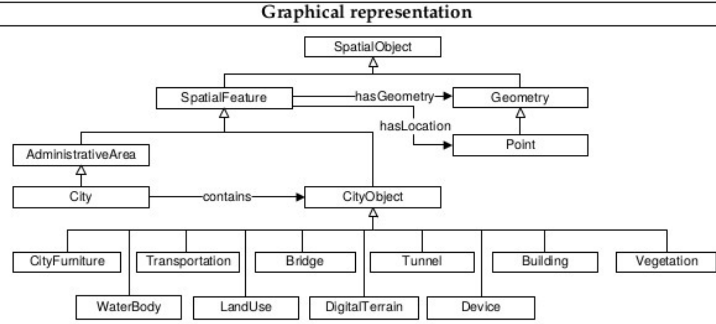
Name	City Object
Description	
This pattern provides a model for an object that belongs to a city.	
Requirements	
OBJ-1:	A city object can be defined by a geometry.
OBJ-2:	A city object can be located in a given point.
OBJ-3:	A city can have city objects.
OBJ-4:	Each city object can have a location.
OBJ-5:	Some specific types of city objects can be: automated external defibrillator, urban furniture (bench, basket, street lights, etc.), cameras, or monuments.
OBJ-6:	A spatial thing can be a city object.
Graphical representation	
	
Use Case	
A garbage container can be located at a given point in a street. By means of a sensor installed inside of the container, it could be possible to detect whether it is full. It could be used to redirect the waste truck route in order to optimize waste management. In addition, it could be used to send a notification to citizens in order to announce the proximity of the waste truck.	
Note	The OBJ-5 requirement may be modeled by means of the *CityObject* subclasses. For example, a sensor may be represented as a subclass of *Device*.

Figure 1: *City object* pattern [4].

Use case illustrated by this pattern is described as follow

: *A city council usually provides a training service. The municipal council can have a register with the geometry of all the stations. These stations offer a parking service, which can contain parking spaces defined by geometries. These slits could be supervised by certain sensors located at a given point. Passengers could use a mobile application to obtain real-time information on the available location, and thus, they could calculate the estimated time they will spend between parking their car and boarding the train [4].*

This review on what the literature says about the pattern concept and smart cities shows that many patterns have been found in the literature. But as many of them are issued from inferential analysis such as those presented in [2, 21, 18, 14], or are from descriptive analysis such as those presented in [19, 20, 13, 5, 15] patterns remains under the form of statistical motifs that very complex to handle as they are not easy readable nor easy understandable in addition they are not integrated as they consider one critical dimension of a smart city at the time.. In contrary ontological patterns proposed by [4] are very readable but they are not really integrated as they consider one critical dimension of a smart city at the time.

We need to check the literature to see if there are patterns allowing to integrated many critical dimensions of a smart city.

C. Data integration in the smart communities and cities framework: litterature review

For the purpose of data integration, many software applications have been developed as shown in [20] where a framework, a Smart City Object API is presented to create a dynamic service ecosystem and adaptive in future digital cities, or in [1] where the authors present UBra-BIGSEA a platform to create data analysis workflows that provides better data quality as well as advanced services for sentiment analysis, estimation of traffic road congestion and recommendation of trips according the estimated density. In [12], the authors also propose a service-oriented architecture (SOA) for IoT-sensitive intelligent transport systems running on an intelligent network dorsal, while in [17], they propose Euphoria, an asynchronous event-based and implementation software architecture that allows flexible interactions between heterogeneous input/output devices in complex intelligent environments. Finally, in kolaric2019dbl, we find a description of a proposed IoT platform for IoT data management in an intelligent city based on open standards and designed from the outset to efficiently store, manage and present large sets of BIMs and geo-referenced 3D data and also in [11] where the authors present a smart asset alignment framework that can connect to city services in an integrated and holistic solution. The latter proposed framework would promote a seamless connection between the health service, the education service and the social services, without the citizen having to engage with individual services.

Some have highlighted some challenges regarding the opportunity to integrate data into smart cities, as did Becker et al. in becker2019pervasive when discussing challenges like interoperability, end users with little or no knowledge and interest in configuration, IT technology, complexity, etc. increase in redundant data, accessibility data, time consumption in data modeling and movement of data from heterogeneous sources to a central database as shown in figure 2. In offiatheoritical, especially to manage these challenges, they proposed a logical approach to data management using RESTview technology to integrate and analyze data, without fully adopting traditional processes.

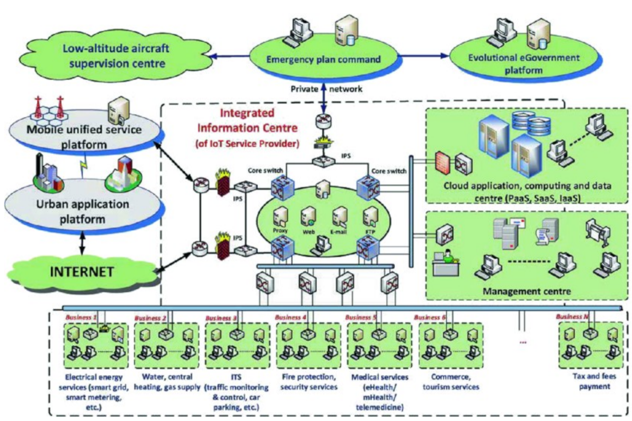


Figure 2: Smart IoT architecture [16].

II. Proposed patterns and methodology

In this section we present the technological-based environment for our proposed conceptual framework for semantic data integration.

The term ONTOLOGY is a Greek word meaning *study of the general properties of what exists*; it refers to a structured set of knowledge in a particular area of knowledge. Ontologies allow you to accurately represent a body of knowledge or concepts in a computer-usable form.

In the case of our conceptual framework, we generally distinguish two global entities within an ontology.

The first, with a terminological objective, defines the nature of the elements that make up the domain of the ontology in question, just as the definition of a class in object-oriented programming defines the nature of the objects that will be manipulated later. The second part of an ontology explains the relationships between several instances of these classes defined in the terminology section. Thus, within our ontology, concepts are defined in relation to each other in our graphic model of knowledge organization, which allows the reasoning and manipulation of knowledge.

To make our ontology comprehensible to the computer, we use the WEB ONTOLOGY LANGUAGE (OWL), which is a knowledge representation language built on the RDF data model.

We will use the version *Description Logics* (DL) of the OWL language which offers good expressivity and is based on descriptive logic.

We choose to represent and organize the concepts we want to integrate in the context of the smart city, in a graph based on properties whose relations can be semantic relations or composition and inheritance relations in the object sense because the graphical representation is more intuitive and more natural for complex ontologies.

The heterogeneous data to integrate is organized into domains, classes, properties, class instances, and relationships between those instances. Heterogeneous data are organized according to their origin or source. Data from the same source is part of the same DOMAIN. Basic concepts in a domain correspond to CLASSES and class members are INDIVIDUALS. On this taxonomy of classes and individuals, PROPERTIES allow you to first establish a relationship and also to state facts about classes or individuals.

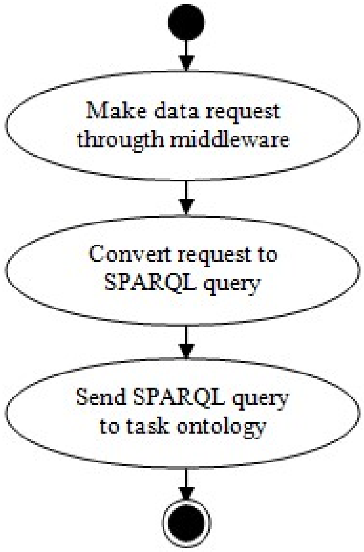
The proposed framework is based on the following triple (Subject, Predicate, Object) where:

- Subject - a ressource that can be identified by a URI,
- Predicate - a specification reused and identified by the relation URI,
- Object - a ressource or a constant linked to the subject.

We can visualize triplets as a related graph. Graphs consist of nodes and arcs. The subjects and the objects of the triplets form the nodes of the graph; predicates form arcs.

To represent our proposed patterns, we use two formalism:

1. the activity diagram: it is a graphical description of a business process or algorithm and its parallel and conditional activities in detail;
2. the block definition diagram: it is a hierarchy of blocks linked together by relations specifying the nature of their dependencies, their hierarchy or the entities from which they derive, etc. The block diagram is used to represent blocks, their properties, and their relationships, and defines a set of instances that share the same properties, but each with a unique identity. The block is a delimited and decomposable entity that encapsulates attributes (state variables), properties, and operations (behavioral procedures)



[Activity diagram]

[Bloc diagram]

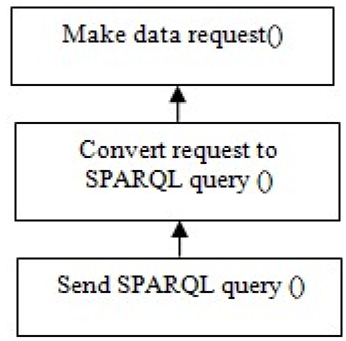


Figure 3: Users application layer pattern

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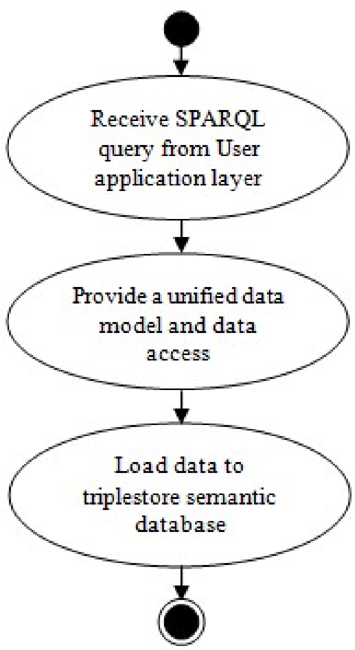
As shown on Figure 3, user does some data request through the middleware. For his queries, user uses the Web browser or the special-purpose client to visit the application server data layer. User uses keywords to write his query that is convert to a SPARQL query.



[Activity diagram]

[Bloc diagram]

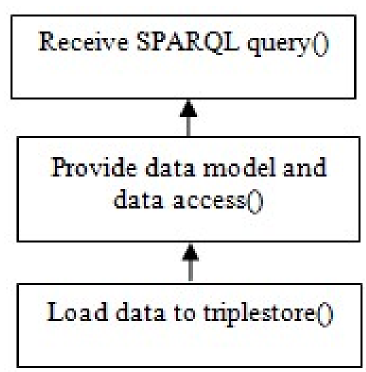
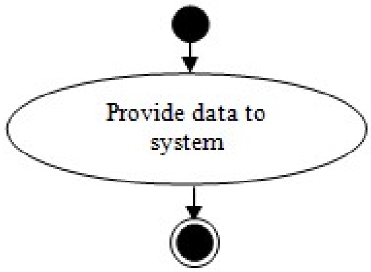


Figure 4: Integration middleware layer pattern

As shown in Figure 4, the *Integration Middleware Layer Model* allows the database system, in other words, the data source layer, to be coordinated, and provides a unified data model and access to the data in the common interface for the application to visit the built-in data upwards. Midleware is a task ontology based on data extracted from source files or databases; the extracted data is transformed and loaded into a triplestore semantic database.

[Activity diagram]



[Bloc diagram]

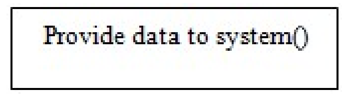


Figure 5: Data source layer pattern

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As shown in the figure 5, the *data source layer model* is the data provider in the system; it includes all types of databases, object databases, relational databases, document formats, multimedia and other information. On this layer, data sources are always stored in the local data source to ensure total autonomy.
Once integration is complete, our data integration framework allows to mask differences between heterogeneous data sources; it also performs a unified operation per heterogeneous data integration system and also allows for the fact that no differences appear between the different data to users. An *Extract Transform Load* (ETL) tool is used to extract, transform, and load data from the data provider to the triplestore of task ontology.

III.Conclusion and future works

In this paper, we have presented a set of patterns for smart city semantic data integration pattern. We have presented the *Users application layer pattern*, the *Integration middleware layer pattern*, and the *Data source layer pattern*. For each pattern, we have presented it diagram activities and it bloc diagram. Future works will consist in the proposition of more patterns, as well as an intelligent system being able to look for a specific pattern in our repository of patterns.

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