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TOWARDS A FRAMEWORK FOR CONTEXT-AWARE INFORMATION SYSTEMS: A METAMODEL-DRIVEN DEFINITION AND IMPLEMENTATION

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ABSTRACT

Context-awareness has captivated a lot of attention, especially in the field of pervasive and mobile computing which gives the naissance of the concept of smart cities in the last decade. Doubtless an important demand for real-world location data inner the virtual world is expanding. Nevertheless, users' context is more than its location. Most context-aware information systems do not take into account the diversity of users' preferences and needs because of its complexity to manage. A key element in the design of context-aware systems is the representation and management of context and of its attributes, to be able to define a relationship between each context and the aspects of interest. In this sense, the objective of our paper is to present a generic context metamodel for the development of context-aware systems. The automation that context-aware systems give can solve many problems and contributes to the concretization of the concept of the smart city. In this paper, we present our context-aware traffic light control system architecture and its implementation as a use case for our contribution which is the generic context framework for context-aware systems.

Keywords: context-awareness, context-metamodeling, software engineering, congestion, context-aware traffic light control system.

1. INTRODUCTION

The concept of "smart city" has become very popular in the last two decades. Thanks to the prime role of cities in the economic growth. Thus, the development of cities has a great impact in the social and economic aspects. Although the concept of "smart city" has not yet a widely and formal accepted definition. We can consider the definition presented in [1] of the concept of smart city: "Smart cities are cities strongly founded on information and communication technologies that invest in human and social capital to improve the quality of life of their citizens by fostering economic growth, participatory governance, wise management of resources, sustainability, and efficient mobility, whilst they guarantee the privacy and security of the citizens [1]."

Hence the objective of smart cities is offering to the citizens a better quality of services and ameliorate the use of public resources and try to problems of the daily life (e.g. the traffic congestion).

Talking about smart cities/ spaces/ objects lead us to the important role of context-awareness concepts in our surroundings. The concept of context-awareness can be used to decide what information of service choose to be presented to the user (citizen in the case of smart city).

The development of context-aware systems has exceeded the domain of ubiquitous computing, to mobile and web-based context-aware systems. Indeed context-aware systems have the ability of monitoring and exploiting external information. Thus, in order to provide context-aware systems we should understand the collected context data by providing services to users capable of managing multiple types of context with consideration of the notion of time. The key notion of those systems is the notion of context which had been the main object of many researches. Indeed, various research papers define only context applications models or systems concerned worrying less about the metamodels that supports these models.

In the other hand, due to urbanization the number of vehicles has expanded in the last years and its resulting traffic congestion has become a real challenge.

This paper aims at supporting the development of context-awareness paradigm by presenting a comparative study of different proposed context definition throughout the last twenty-three years. A discussion of different aspects of this notion with a synthesis is also provided. Based on our previous work [2], we present a new definition of the context notion using a context metamodel, which defines our vision of this notion with its different concepts. Finally, we present our context-aware traffic light control system, which is a case study of our vision of context, and its implementation results.

The remainder of this paper is organized as follows. Section 2 presents a state of the art related to the understanding of the concept of context. Then we present our definition of the concept of the context in section 3. Section 4 presents a case study based on an instant of our context metamodel for the realization of context-aware traffic light control system to contribute in building a Moroccan smart city. Finally, section 5 concludes the paper and presents further work.

2. CONTEXT AWARENESS FUNDAMENTALS

While the notion of context is recognized as a factor in improving the quality of Ubiquitous Systems, there is currently no consensus on a clear, precise unique definition leading to operational exploitation. It must be said that a serious analysis of this notion is being conducted correlatively with the evolution of context-aware technologies. In this section, we will advance the state of the art related to the understanding of the concept of context and its associated concepts.

A. Definition of the context: Literature review

Same examples of the context concept in ubiquitous computing: (1) related to the user (e.g. his/her geographical location, identity, native language…). (2) related to external environment (e.g. temperature, probability of precipitation…). (3) related to the used appliance (e.g. screen size, network bandwidth, processor load…).

More than 200 definitions were proposed about the term context thus the definition of what to consider as context varies highly across different fields. The word Context has given birth to a prominent research field which emerged in the early 90's. First "Context" derived from the Latin con (with or together) and texere (to weave). From the artificial intelligence perspective, this notion could have many definitions in the literature depending on its use. [3] defined context as "interrelated conditions in which an object exists or occurs" which means that the context has a bilateral relation between occurring conditions. Examples [4] and synonyms as "situation and environment" [5-9] was also used to define context. This had derived some researchers to propose a system-oriented definition of the context like [10] who claimed that "context can be considered to be everything that affects the computation except the explicit input and output" which means that the user is replaced by the application. We can observe that those definitions lacks of generality.

Trying to solve this problem [11] proposed another definition, the context is "any information used to determine the situation of an entity". An entity could be a person, place, or object that is considered relevant to the interaction between a user and an application, including location, time, activities, and the preferences of each entity. In a similar sitting [12] tried to give an operational definition of the context by classifying the context into one of the following five categories:

- Individuality context includes properties and attributes defining the entity within the context (e.g. language, behavior, preferences and goals of a learner, in the case that the learner is the entity [13]).
- Time context includes all temporal coordinates (e.g. points in times, long-term courses).
- Location context includes all spatial coordinates, for instance physical location, location in relation to people or resources, or virtual location (IP address).
- Activity context is concerned with all tasks, goals and actions the entity may be involved in goals, tasks and actions.
- Relations context captures information about any possible relation the entity may establish with another entity (social, functional and compositional relations) of example with the students, teachers and resources.

At the early age of the nineteens' most definitions were from a static view but [14] tried to formalize the context concept, from a dynamic perspective, by considering that the context cannot be described completely and is always relative to another context; and that the context has an infinite dimension [15].

Following this discussion about the static and dynamic aspects involved in the manipulation of context, [16] considered the two main aspects of context: context as a representational problem and context as an interactional problem. Then he claimed that the aspect that notices the interaction of objects is the correct one and not just the representational one.

Hence, it is challenging to define the word 'context' and many researchers tried to find their own definition for what context actually includes. For instance, in [17] we can say that this term is mostly adopted to indicate a set of attributes that characterize the capabilities of the access mechanism, the preferences of the user, and other aspects of the context in which information and services are delivered, these may include the access device (even in the presence of strong heterogeneity of the devices) [18].

Moreover, the critical importance of this concept has been the inspiration of several studies which gave multiple ramifications of its dimensions: spatial, spatial mobility, spatiotemporal, environment and personal dimension [18]. And so many efforts have been made since to categorize contexts: personal context which includes (physical and mental context); physical and conceptual context; physical and logical coordinate; while others consider state-based and event-based context as a categorization [19]. [20] categorized through tree main categories: (1) Physical environment context, it concerns the physical world (time, temperature, etc; (2) User context (preferences and needs...); (3) Virtual environment context where each component of the distributed system is aware of existing services.

[21] Categorized context into three categories using a conceptual categorization based technique on three main questions that can be used to determine the context [22]:

i. **Where are you:** all location related information such as GPS coordinates, common names (e.g. coffee shop, university, police), specific names (e.g. Canberra city police), specific addresses, user preferences (e.g. user's favorite coffee shop).
ii. **With whom are you:** includes information about the presented people around the user?
iii. **What resources are near you:** the information about resources available in the area where the user is located, such as machinery, smart objects, and utilities?

This categorization is also termed as the operational vs. conceptual context by [23]:

a) **Operational categorization:** Categorize context based on how they were acquired, modeled, and treated.
b) **Conceptual categorization:** Categorize context based on the meaning and conceptual relationships between the context.

While [24] identified the five W's (Who, What, Where, When, Why) as the minimum information that is necessary to understand context. In the same sense [25] distinguished between two type of context, primary and secondary context:

- **Primary context:** Any information retrieved without using existing context and without performing any kind of sensor data fusion operations (e.g. GPS sensor readings as location information).
- **Secondary context:** Any information that can be computed using primary context. The secondary context can be computed by using sensor data fusion operations or data retrieval operations such as web service calls (e.g. identify the distance between two sensors by applying sensor data fusion operations on two raw GPS sensor values). Further, retrieved context such as phone numbers, addresses, email addresses, birthdays, and list of friends from a contact information provider based on a personal identity as the primary context can also be identified as secondary context.

Moreover, there are several other schemes that were introduced by different researchers focusing on their own perspectives. Thus Table-1 summarizes the main context categories considered in previous context classifications. We have classified different proposed context vision into six categories (see Table-1), which are: Context Definition, Context Element, Context Levels, Context Type, Context Nature, and Context Exploitation. Those schemes are not distinct from each other, they could share common characteristics.

Despite the fact that there are several definitions of the concept of context, researchers agree on the following points:

a) Context exists only when related to another entity (e.g. task, agent or interaction);

b) Context is a set of items (e.g. concepts, rules and propositions) associated to an entity;

c) An item is considered as part of a context only if it is useful to support the problem [15]. Let's consider the information "it's snowing". This proposition is considered as a part of the context in a traffic jam support system since snow has consequences on speed, visibility and therefore in the traffic. Yet, the same information has not contextual information in a museum guide system.

Most prominent context definitions generally refer to the whole situation relevant to an application and its users.

B. Context awareness

Throughout the evolution of the notion of context contributes on the nascence of various systems dependent on this latter. In particular, the appearance and penetration of mobile devices such as notebooks, PDAs, and smart phones, has led to the introduction of pervasive (or ubiquitous) systems which are becoming increasingly popular. First introduced by Weiser [26] the term 'pervasive' refers to the complete integration of devices into the user's everyday life.

Weiser said that "the most profound technologies are those that disappear. They weave themselves into the fabric of everyday life until they are indistinguishable from it."

This was a vision too far ahead of its time because the hardware technology needed to achieve it did not exist yet. In the last decade this vision is becoming a reality.

The notion "Context awareness" was first introduced by Schilit and Theimer [3] in 1994. Later, [30] tried also to define context awareness but those definitions are too specific [10] for identifying a system whether is it context aware or not. While Dey defines the term context-awareness by "A system is context-aware if it uses context to provide relevant information and/or services to the user, where relevancy depends on the user's task [10]".

Hence we call Context Aware Systems (CAS) the computer systems that use context to provide relevant information or services to improve user's awareness while performing their tasks by providing adaptation that ease's the task execution.

C. Synthesis

In Table-1 we have classified different context definitions scanned from the literature into six categories which are:

a) **Context definition by five different types:**
- Definition by examples.
- Definition by categories.
- Definition by synonyms.
- Definition by social information.
- Definition by the domain of use.

b) **Context element by ten different types:**
- The five W's question: Location (Where), User (Who), Time (When), Activity (What) and Objective (Why).
- Task
- Conditions
- System (Computing)
- Environment (Physical)
- Historical interaction

c) **Context levels by two levels:**
- Low-level /physical
- High-level / Logical

d) **Context type by fore types:**
- Derived

- Profiled
- Primary context
- Secondary context

e) **Context nature by two types:**
- Static
- Dynamic/Sensed

f) **Context exploitation by two types:**
- Rules
- Services

Yet, proposed context definitions still limited. We have found user-oriented approaches or other object oriented approaches that focus on context, interaction, devices, interoperability, or services. We have presented previously the main existing context modeling approaches.

Despite each approach can provide effective results for a particular domain, and / or a particular type of reasoning, none of them can provide a complete solution, from the data capturing to the high-level context data delivering. Likewise, none of the presented visions can satisfy all the requirements illustrated previously in the introduction.

Therefore, a complete and global context definition is required, covering all the needed context-aware concepts (i.e. user profile, preferences, user activity, history, interaction, location, environment, devices, services, activities, etc.). That is why the next section is dedicated to the introduction of our context language illustrated by a context metamodel.

3. THE PROPOSED CONTEXT METAMODEL DRIVEN DEFINITION

In this section, we present our generic context metamodel context-aware systems (see Figure-1). We use the Ecore metamodeling language of the EMF component for the (representation of) definition of our context metamodel.

A context metamodel must address special requirements of pervasive computing environments. Besides context-aware applications require high-level context information that is derived from low-level context values [43].

In our vision the concept of context interacts three different elements which are:

- The User with its properties.
- The System with its properties.
- And the external/ physical Environment.

Therefore, we designed the conceptual basics of our framework first, starting with context metamodeling, as our paramount concern, that translate our vision.

As you can see in Figure-1, our context depends on three major elements which are the system, user and the environment. We define the context as an aggregation of seven different main groups of properties (see Figure-1): The channel, location and time, user profile, system activity, history, rules, and external environment.

- A Channel defines the medium by which information of the context can be transmitted; it identifies the physical device and the connection used to access the application. The Channel is composed of:

❖ The Device used for the communication, we adopt the Device model proposed by [17];
❖ The Network used to transfer information;
❖ The Application protocols used by services.

- A Location and Time description that identify the position of the user; where the user is located while interacting with the application and the Time of the interaction. It is composed of two main parts:

❖ Political Location describes the location in terms of Country, City and street.
❖ Physical Location describes the location in terms of Geography location using GPS.

- The User profile is, none other than, the information collected, structured, organized, and maintained about user-related data [44]. We classify the data concerning a user, as mentioned in the context metamodel in Figure 1, into two different groups [12]:

❖ **Static data:** such as First name and Last name, age (Date of birth), gender, and personal information that the user could express explicitly like his address.
❖ **Dynamic data:** are the information that could be changed manually by the user or automatically by the application such as: user's Expertise and knowledge, the Role played by the user in social context and Medical state of the user that is helpful (e.g. in a health application). The Dynamic part of the user is composed of User activity which describes if he/she is Mobile or Fixe.

- System Activity that describes relevant information about the ongoing activities in which the user and the system are involved, which could be known from the state of the system (Stand-by, Acquisition, Offering or Searching mode).
- A History of context action interactions that the user has performed with the application implemented.
- Preferences formulated implicitly by means of association Rules extracted from the above-mentioned history, or were set by a domain expert. An example of a rule in a tourism application would be: IF a user is a student, requesting from Venice, asking for a service belonging to Service Hotel Reservation THEN the user prefers 3stars category, room with TV.

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- External Environment information which describes Temperature and UV Index, Probability of precipitation, time of sun set and sun rise.

In the next section, we present our context-aware traffic light control system architecture and its implementation results.

4. VALIDATION OF THE PROPOSED METHOD: A CONTEXT-AWARE TRAFFIC LIGHT CONTROL SYSTEM

Road networks have experienced a significant increase in their distribution over the last decade. Increasing urbanization and the increase use of vehicles in daily commuting generate congestion problems, particularly in urban areas. In this section before presenting the proposed context-aware traffic light control system we raise the need of this kind of systems and their impact.

A. Problems

After a deep review of several operational traffic lights systems [39-42] in different places in densely populated cities. A number of resulting problems could be raised as follows:

- As shown in Figure-2. traffic congestion occurs at the main junction points particularly in rush hour (the red color is the slowest road, green for the normal traffic with no over waiting time, and orange means there is some congestion in that road).
- In our country, and most developing countries, solving congestion traffic problems at the rush hour are done manually by the traffic official.
- Waiting times are longer.
- Increasing fuel consumption.

Table-1. Context categorization schemes in context classification works.

Approaches		**[3]**	**[21]**	**[29]**	**[5]**	**[30]**	**[11]**	**[31]**	**[28]**	**[32]**	**[33]**	**[34]**	**[9]**	**[35]**	**[12]**	**[36]**	**[37]**	**[38]**	**[15]**	**[27]**	**[19]**	**[22]**	**The proposed**
Context Definition	Example	√			√	√												√					
	Categories	√																					
	Synonyms	√		√																			
	Social			√	√	√	√	√			√				√			√			√		
	Domain												√										√
Context Element	Location (Where)	√	√	√	√	√		√			√		√		√	√		√	√	√			√
	User (Who)	√	√		√	√	√	√			√			√	√	√		√	√	√	√		√
	Time (When)		√	√	√	√	√	√			√				√			√	√	√	√		√
	Activity (What)	√					√							√					√	√	√		√
	Objective (Why)						√																√
	Task							√			√				√								
	Conditions										√												
	System (Computing)		√								√		√	√		√					√		√
	Environment (Physical)		√	√	√	√		√			√		√	√				√			√		√
	Historical interaction													√							√		√
Context Levels	Low-level /physical									√							√						√
	High-level / Logical									√							√						√
Context Type	Derived								√			√											√
	Profiled								√			√											√
	Primary Context																					√	
	Secondary Context																					√	
Context Nature	Static								√											√			√

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	Dynamic/ Sensed								√			√											√
Context Exploitation	Rules																		√	√			√
	Service																				√		√

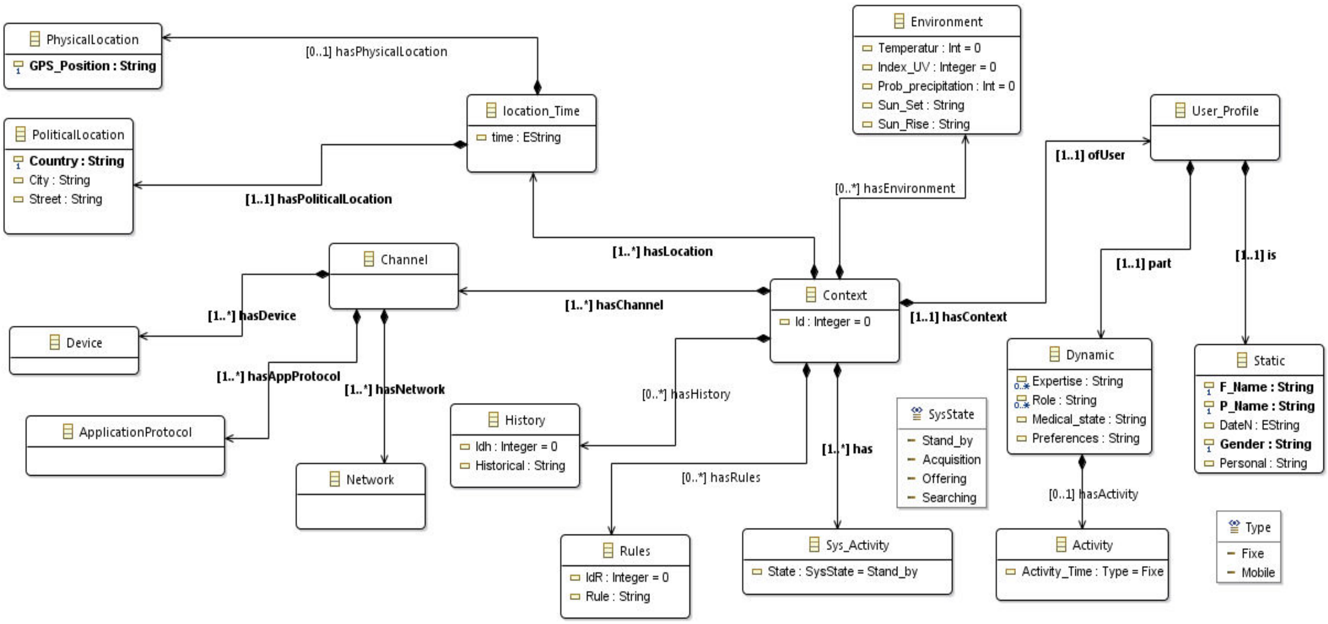

Figure-1. Our proposed context metamodel.

Figure-2. A satellite image of a real traffic congestion in the center of Rabat the capital of Morocco.

- Increased stress among drivers.
- The traffic light control systems existing provide the same duration for the green light to different traffic lane

Until today (the time writing this manuscript), there is no intelligent traffic control system in our country, that provides priority to a traffic lane.

B. Aims and scope of this study

The present study is a case study for the future Moroccan smart city "Cité Mohammed VI Tanger Tech"[1]. In this sense we would like to contribute to the evolution of our country and the technology of smart cities by proposing an intelligent (context-aware) traffic light control system. Our objectives are:

- Regulating parameters for managing traffic in junction points to smooth the flow of the road network.
- Reduce the waiting time for each vehicle.
- Remove the old manual traffic system for solving congestion problems.
- Provide an intelligent traffic control system that provide priority to a traffic lane.
- Afford effective information to the traffic control authority for a better evaluation and traffic control.

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- Inform users of the waiting time remaining and the proposal of alternative itinerary in case of knowing their destinations.

C. The proposed context-aware traffic light control system architecture

In this section, we present the context-aware traffic light control system architecture in Figure-3 our architecture is composed of:

- Surveillance camera: it allows real-time visualization of digital images from video cameras.
- Acquisition module: sensors which receive and store video signals from the cameras.
- Image processing: thanks to a DSP (Digital Signal Processor) which is a microprocessor optimized for executing digital signal processing applications in real time, a digital signal processing algorithm is applied to the captured image
- Conversion: with CAN bus captured signals are conversed into digital signals.
- Processing module: module which measures in real time the real traffic demand and the capacity offered by a road on a crossroads and provides this information in a directly usable way by the lights controllers at the crossroads.
- Control module: provides the color of the lights of the crossroads controlled by the processing module.
- Context-aware module: its role is to provide automatic and dynamic services to the user in real-time according to the contextual information. This module deals with contextual changes that occur at runtime, and so on its inputs are:
- The waiting time of each vehicle measured by the processing module.
- Contextual information that are useful if this kind of application like user's position, user's direction and user profile…
- While the outputs of the context-aware module are services to the user (or driver): the waiting time and redirection to another flowing road. In the case of a smart city where all the crossroads are intelligent so the waiting time of each one is known and we can provide to the driver the less crowded road.

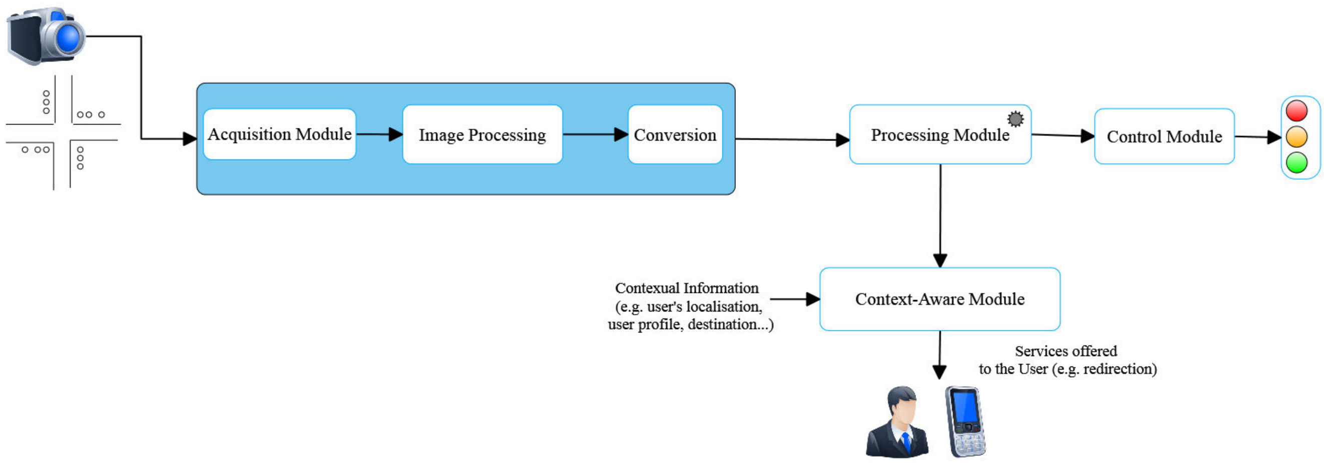

Figure-3. The context-aware traffic light control system architecture.

D. The context-aware traffic light control system implementation

We have developed our system using SystemC languages which provide an event-driven simulation interface. SystemC is a subset of the ANSI-C ++ language combined with a set of libraries that support the specification, simulation and synthesis of complex digital systems. Also, it can communicate in a simulated real-time environment, using signals.

As the proposed algorithm of the traffic light control shows, the microprocessor receives the number of vehicles (NV) detected by the cameras in each line and takes the maximum number (*Max_number_vehicles*):

1. **The first case (Normal traffic):** If the maximum number (Max_number_vehicles) is lower or equal to the number of vehicles (NV) then it gives the hand to the tracks in turn for a waiting time (*WT*) in our study it is 30 seconds.
2. **The second case (The traffic threshold):** if the takes the maximum number (Max_number_vehicles) is higher than the number of vehicles (*NV*) then it gives the hand to the track that has the max number of vehicles.

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The simulation results of SystemC program describing the plotting of the output signals had shown good results of the automation of traffic light control system (as shown in Figure-4).

For each controller x the controller send a signal out(x) which takes 0 or 1 with x = {1, 2, 3, 4}

a) 0: lights of line x must light the red light.
b) 1: lights of line x must light the green light (see Figure-5).

Algorithm 1 Traffic Lights in the Intersection

Detect the number of vehicles in each road (NV)
while (*infinite loop*) **do**
  if $NV < Max\_number\_vehicles$ **then**
    (*Normal Traffic*)
    for $i = 1 \rightarrow 4$ **do**
      Traffic light is green in the road(i) for a waiting time (WT)
      Traffic light are red in other roads for the WT time
    end for
  else
    (*The traffic threshold*)
    for $i = 1 \rightarrow 4$ **do**
      if *In the road(i) the maximal number of vehicles* **then**
        Traffic light is green in the road(i) for a waiting time (WT)
        Traffic light are red in other roads for the WT time
      end if
    end for
  end if
end while

5. CONCLUSION AND FUTURE WORK

In this paper, we have presented a context-aware traffic light control system. To achieve this, we defined our context through a context metamodel, which is the continuation of our previous works [2], after conducting an in-depth study of what exists in the literature about the context concept and its modeling and having synthesized it.

The result of this paper is used to overcome the traffic congestion of the road and minimize the waiting time of each vehicle in the road. Moreover, the proposed context-aware traffic light control system could be used for the analysis of different road traffic congestion.

For a future work, we will add (RFID) sensors to the intelligent traffic light control system to assure a safe and clear path emergency traffic such as for ambulance cars and/or fire brigade buses.

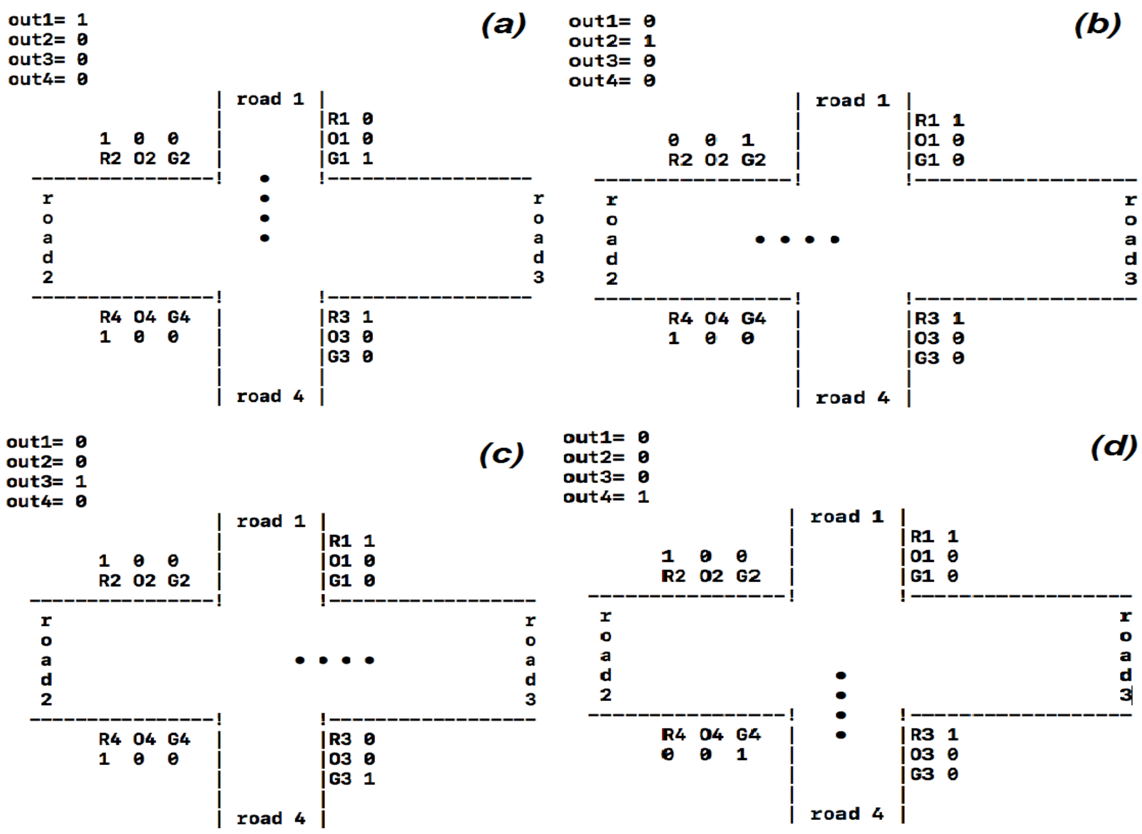

Figure-4. The light display for each lane and the microprocessor outputs (out1, out2, out3, out4) for the fore cases. (a/ b/c/d): the road (1/2/3/4) has the maximum number of vehicle so the light turns to green and other one to red.

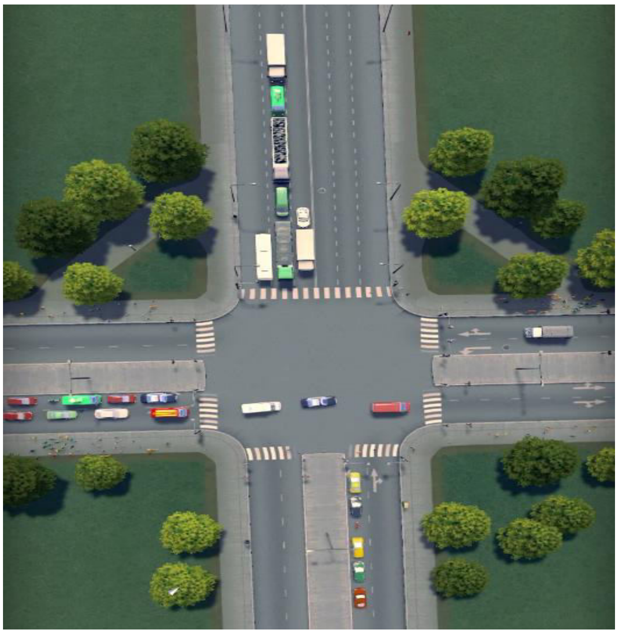

Figure-5. The visualization of the case (b) with Anylogic[2].

REFERENCES

[1] Solanas A., Patsakis C., Conti M., Vlachos I. S., Ramos V., Falcone F. and Martinez-Balleste A. 2014. Smart health: a context-aware health paradigm within smart cities. IEEE Communications Magazine. 52(8): 74-81.

[2] Aarab Z., Saidi R. and Rahmani M. D. 2014. Towards a framework for context-aware mobile information systems. In: Signal-Image Technology and Internet-Based Systems (SITIS), 2014 Tenth International Conference on. IEEE. pp. 694-701.

[3] Schilit B.N., Theimer M. M. 1994. Disseminating active map information to mobile hosts. Network, IEEE. 8, 22-32.

[4] Brown P.J. 1995. The stick-e document: a framework for creating context-aware applications. Electronic publishing. 8, 259-272.

[5] Brown P.J., Bovey J.D., Chen X. 1997. Context-aware applications: from the laboratory to the marketplace. Personal Communications, IEEE. 4, 58-64.

[6] Ward A., Jones A., Hopper A. 1997. A new location technique for the active office. Personal Communications, IEEE. 4, 42-47.

[7] Hull R., Neaves P., Bedford-Roberts J. 1997. Towards situated computing. In: Wearable Computers, 1997. Digest of Papers, First International Symposium on, pp. 146-153. IEEE.

[8] Franklin D., Flaschbart J. 1998. All gadget and no representation makes jack a dull environment. In: Proceedings of the AAAI 1998 Spring Symposium on Intelligent Environments. pp. 155-160.

[9] Rodden T., Cheverst K., Davies K., Dix A. 1998. Exploiting context in HCI design for mobile systems. In: Workshop on human computer interaction with mobile devices, pp. 21-22. Citeseer.

[10] Lieberman H., Selker T. 2000. Out of context: Computer systems that adapt to, and learn from, context. IBM Systems Journal. 39, 617-632.

[11] Abowd G.D., Dey A.K., Brown P.J., Davies N., Smith M., Steggles P. 1999. Towards a better understanding of context and context-awareness. In: Handheld and ubiquitous computing, pp. 304-307. Springer, 1999: URL http://dl.acm.org/citation.cfm?id=647985.743843 (accessed on 16 June 19, 2017).

[12] Zimmermann A., Lorenz A., Oppermann R. 2007. An operational definition of context. Modeling and using context. pp. 558-571. Springer.

[13] Hum S. B. & Ferguson R. 2012. Social Learning Analytics. Educational technology & society. 15(3): 3-26.

[14] McCarthy J. 1993. Notes on formalizing contexts. In 13th international joint conference on artificial intelligence, pp. 555-560. San Mateo, California.

[15] V. Vieira, P. Tedesco, and A. C. Salgado. 2011. Designing context-sensitive systems: An integrated approach. Expert Systems with Applications. 38(2): 1119-1138. doi:10.1016/j.eswa.2010.05.006.

[16] Dourish P. 2004. What we talk about when we talk about context. Personal and Ubiquitous Computing. 8, 19-30.

[17] M. Adorni, F. Arcelli, S. Bandini, L. Baresi, C. Batini, A. Bianchi, D. Bianchini, M. Brioschi, A. Caforio and A. Cali. 2006. Reference Architecture and Framework, in Mobile Information Systems, Springer. pp. 25-46.

[18] B. Pernici. 2006. Basic Concepts, in Mobile Information Systems, Springer. pp. 3-23.

[19] Emmanouilidis Christos, Koutsiamanis Remous-Aris and Tasidou Aimilia. 2013. Mobile guides. Taxonomy of architectures, context awareness, technologies and applications. Journal of Network and Computer Applications. 36(1): 103-125.

[20] Poslad S. 2011. Ubiquitous computing: smart devices, environments and interactions. John Wiley & Sons.

[21] B. Schilit, N. Adams, and R. Want. 1994. Context-aware computing applications, in Mobile Computing Systems and Applications, 1994. Proceedings. Workshop on, pp. 85-90. [Online]. Available: http://dx.doi.org/10.1109/MCSA.1994.512740 (accessed on 16 June 19, 2017).

[22] Perera C., Zaslavsky A., Christen P., Georgakopoulos D. 2014. Context aware computing for the internet of things: A survey. Communications Surveys & Tutorials, IEEE. 16(1): 414-454.

[23] Van Bunningen AH, Feng L, Apers PMG. 2005. Context for ubiquitous data management. International Workshop on Ubiquitous Data Management (UDM2005). Tokyo, Japan. pp. 17-24.

[24] G. D. Abowd and E. D. Mynatt. 2000. Charting past, present, and future research in ubiquitous computing, ACM Trans. Comput.-Hum. Interact. 7: 29-58. [Online]. Available: http://doi.acm.org/10.1145/344949.344988 (accessed on 16 June 19, 2017).

[25] De Matos E., Amaral L. A., & Hessel F. 2017. Context-Aware Systems: Technologies and Challenges in Internet of Everything Environments. In Beyond the Internet of Things Springer International Publishing. pp. 1-25.

[26] M. Weiser. 1991. The computer for the 21st century. Scientific American. 265(3): 94-104.

[27] Ben Cheikh, A., *et al.* 2012. An engineering method for context-aware and reactive systems. In: Research Challenges in Information Science (RCIS), 2012 Sixth International Conference on. IEEE. pp. 1-12.

[28] K. Henricksen. 2017. A framework for context-aware pervasive computing applications. Computer Science, School of Information Technology and Electrical Engineering, The University of Queensland, September 2003, http://henricksen.id.au/publications/phd-thesis.pdf (accessed on 16 June 19, 2017).

[29] Brown PJ. 1996. The Stick-e document: A framework for creating context-aware applications. Proceedings of Electronic Publishing. pp. 259-72.

[30] Ryan NS, Pascoe J, Morse DR. 1997. Enhanced reality fieldwork: The context-aware archaeological assistant. Proceeding of the 25th Anniversary Computer Applications in Archaeology. University of Birmingham. pp. 269-74.

[31] Goker A, Myrhaug H. 2002. User context and personalization. Proceedings of the European Conference on Case Based Reasoning (ECCBR 2002) - Workshop on Personalized Case-Based Reasoning. Aberdeen, Scotland. pp. 4-7.

[32] D. Guan, W. Yuan, S. Lee, and Y.-K. Lee. 2007. Context selection and reasoning in ubiquitous computing, in Intelligent Pervasive Computing, 2007. IPC. The 2007 International Conference on, pp. 184-187. [Online]. Available: http://dx.doi.org/10.1109/IPC.2007.102 (accessed on 16 June 19, 2017).

[33] Schmidt A, Beigl M, Gellersen H-W. 1999. There is more to context than location. Computers and Graphics. 23: 893-901.

[34] Z. Miao and B. Yuan. 2006. Spontaneous sensor networks for context-aware computing. in Wireless, Mobile and Multimedia Networks, 2006 IET International Conference on, nov. pp. 1-4. [Online]. Available: http://ieeexplore.ieee.org/xpls/abs all.jsp?arnumber=519574 (accessed on 16 June 19, 2017).

[35] G. Jun-zhong. 2009. Context aware computing. Journal of East China Normal University (Natural Science), vol. 5, pp. 1-20. [Online]. Available: http://en.cnki.com.cn/Article en/CJFDTOTALHDSZ200905002.htm(accessed on 16 June 19, 2017).

[36] Grassi V, Sindico A. 2007. Towards model driven design of service-based context-aware applications. International workshop on Engineering of software services for pervasive environments. Dubrovnik, Croatia. pp. 69-74.

[37] S. Rizou, K. Haussermann, F. Durr, N. Cipriani, and K. Rothermel. 2010. A system for distributed context reasoning. in Autonomic and Autonomous Systems (ICAS), 2010 Sixth International Conference on, pp. 84-89. [Online]. Available:

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http://dx.doi.org/10.1109/ICAS.2010.21 (accessed on 16 June 19, 2017).

[38] Garzotto F, Paolini P, Speroni M, Proll B, Retschitzegger W, Schwinger W. 2004. Ubiquitous access to cultural tourism portals. Database and Expert Systems Applications, 15th International Workshop on (DEXA'04). Zaragoza, Spain. pp. 67-72

[39] Riley, D., Nellen, G., Barrera, R., Quevedo, J. 2014. Crowd sourcing traffic simulation to improve signal timing. Journal of Computing Sciences in Colleges. 29(5): 112-118.

[40] Zhang L., Haas C., Tighe and S.L. 2007. Evaluating weigh-in-motion sensing technology for traffic data collection. In: Annual Conference of the Transportation Association of Canada. pp. 1-17.

[41] Jain D.K., Sharma S., Yadav M. 2011. An optimal and dynamic vehicular traffic management system, In: Computer and Communication Technology (ICCCT), 2011 2nd International Conference on. IEEE. pp. 77-81.

[42] Kumar R. and Gupta K. 2016. ITMS (Intelligent Traffic Management System). Proceedings of Fifth International Conference on Soft Computing for Problem Solving. Springer Singapore. pp. 487-495.

[43] Reichle R., Wagner M., Khan M. U., Geihs K., Lorenzo J., Valla M. & Papadopoulos G. A. 2008. A comprehensive context modeling framework for pervasive computing systems. In Distributed applications and interoperable systems, pp. 281-295. Springer Berlin Heidelberg.

[44] Corallo A., Lorenzo G., Solazzo G. & Arnone D. 2006. Knowledge-Based Tools for E-Service Profiling and Mining. In Mobile Information Systems, pp. 265-291. Springer Berlin Heidelberg.