Birlesik Dünya Arastırma BD-CENTER Innovasyon ve Yayıncılık Merkezi

Global Journal of Computer Sciences: Theory and Research

Global Journal of computer sciences Theory and Research

Volume 13, Issue 2, (2023) 92-108 www.gjcs.eu

Developing a new model for context awareness in ambient intelligence

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Suggested Citation:
Abdelkader, B. (2023). Developing a new model for context-awareness in ambient intelligence. Global Journal of Computer Sciences: Theory and Research *13*(2), 92-108.

Received from; July 23, 2022, revised from; August 21, 2022, and accepted from September 11.
Selection and peer review under the responsibility of Assoc. Prof. Dr. Ezgi Pelin YILDIZ, Kafkas University, Turkey.

Abstract

Ontologies are a powerful way to model context, thanks to their expressiveness, ability to share knowledge, support for logical inference, and extensibility. While many generic ontologies capture and represent general context concepts, such as the SOCAM and CoOL projects, they are not tailored specifically for ambient intelligence and smart homes. This research aims to develop a specific ontology for these domains, building on existing generic ontologies and incorporating logical inference capabilities to assist people with reduced mobility and the elderly in carrying out their daily Systems perspective followed by an application of a step-by-step ETL procedure.

Keywords: Ambient intelligence; Context modeling; mobility; Ontology; Smart hose.

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1. INTRODUCTION

The Smart Hose offers a solution for individuals with limited mobility and the elderly, by enabling them to perform daily activities without the constant assistance of a caregiver. The system facilitates or automates the activation of certain services and provides adapted services to users. Smart Hose involves creating smart homes made up of connected objects that can process information and provide services independently.

Ambient intelligence (AmI) is a concept that refers to the integration of advanced technologies into the environment to enhance the user experience and make everyday tasks more convenient and efficient. It aims to create smart spaces that are aware of the user's presence, preferences, and context, and can adapt to their needs in real-time. AmI is based on the idea that technology should be invisible and intuitive, blending seamlessly into the background to enhance the user's natural environment [1], [2]. Subject-Oriented, Time-Variant, and Non-Volatile. Vincent Rainardi relates “A data warehouse (DW) is a system that retrieves and consolidates data periodically from the source

Potential applications of AmI include the following [2], [3]:
Smart homes: AmI technologies can be used to create intelligent environments that can automatically adjust lighting, temperature, and other features to suit the user's preferences and needs.
Healthcare: AmI technologies can be used to monitor patients' vital signs, provide remote consultations, and assist with medication management [4-7].
Transportation: AmI technologies can be used to improve the efficiency of public transportation systems, provide real-time traffic information, and assist with navigation [8].
Retail: AmI technologies can be used to create interactive shopping experiences, provide personalized product recommendations, and assist with inventory management.
Entertainment: AmI technologies can be used to create immersive virtual reality experiences and provide personalized content recommendations.

For Wang et al., [9], ambient intelligence is part of a futuristic vision of telecommunications and the computerization of life, our future environment will be surrounded by different systems and applications that will be carried by network technologies and computing to provide intelligent assistance without human intrusion [10].

In summary, AmI technologies have the potential to enhance the user experience and make everyday tasks more convenient and efficient in a wide range of applications.

Smart hose includes all the electronic, computer, and telecommunication technologies used in the home. Smart hose is the coordination and automation of domestic tasks that include: security, heating and air conditioning, programming of automatic switching on and off of appliances, remote control, etc [1].

Context-aware computing is a computing paradigm in which the system automatically adapts to the current context of the user, such as their location, time of day, and other factors, to provide more relevant and personalized information and services. The goal of context-aware computing is to make the user's experience more seamless and efficient by dynamically adjusting the system's behavior based on the context [11], [12], [13], and [14]. There are three important aspects of the context to know [15]:

- Where is the user?
- With whom is the user?
- What are the means he has?

Context has been taken into account in various fields of computer science, including natural language processing, machine learning, computer vision, decision support, information retrieval, and ubiquitous computing. By analogy to human reasoning, the goal behind the use of context is to add adaptability and best decision-making [15]. An efficient model for processing, sharing, and storing context data is essential to realize a context-aware system. There are several approaches [16] for context representation which are:

- Key-Value Models

The key-value pair model is the simplest data structure for modeling contextual information. This approach, which involves describing services as a simple list of key-value attributes, is widely used in distributed service frameworks [16,17].

- Markup Scheme Models

Markup languages are hierarchical data structures composed of tags with attributes and contents. The contents of the tags are often defined recursively by other tags. The most widely used and well-known markup language is XML, with others including SGML, RDF, etc. [16,17].

- Object Oriented Modeling

In this modeling (fig 1), the object-oriented approach is used to benefit from its main advantages of encapsulation and reuse to cover the problems posed by context dynamics in ubiquitous environments. The details of context processing are encapsulated at the object level and are hidden from other components. Access to contextual information is provided via specified interfaces.

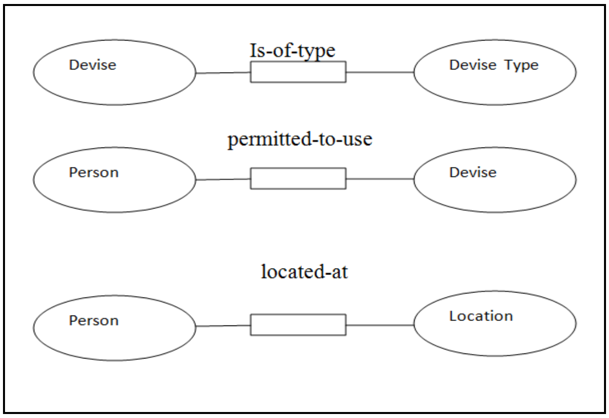

Fig. 1. A context modeling with the Object-Oriented approach

- Graphic Model

  Markup languages are hierarchical data structures composed of tags with attributes and contents. The contents of the tags are often defined recursively by other tags. The most widely used and well-known markup language is XML, with others including SGML, RDF, etc. [16,17].

- Formal modeling (Logic Based Models)
  In this model, conditions are defined under which a conclusion or facts can be inferred from other expressions or facts. These conditions are described in a set of rules. In a formal model, the context is defined as a combination of facts, expressions, and rules.
- Ontology-based modeling
  The term 'ontology' has a long history in philosophy, where it refers to the object of existence. In the field of artificial intelligence, ontology represents a complete or partial knowledge of concepts, their attributes, and the relationships between these concepts [16, 18]. The first definition for ontology in artificial intelligence was given by Gruber: "An ontology is an explicit specification of a conceptualization. The term is borrowed from philosophy, where ontology refers to a set of existing things. For AI systems, what exists is what can be represented." It is important to note that ontology serves as a common vocabulary that defines the meaning of concepts and the relationships between them. This vocabulary can be associated with a model that describes the content of a knowledge base, its properties, how it can be used, and the syntax and constraints provided by the representation language. The use of ontology for user context modeling has many advantages, such as:
  Knowledge sharing: The use of ontology allows computing entities, such as agents and services in ubiquitous computing environments, to have a common set of concepts about context while interacting with other entities.
  Logical inference: Based on the ontology, a context-aware system can exploit various logical reasoning mechanisms to infer high-level context information from low-level context information and the raw context information. It can also check and resolve incompatible context knowledge due to misdetection of information.
  Knowledge reuse: The reuse of existing ontologies enables the creation of new ontologies without starting from scratch.

All these context representation approaches have their strengths and weaknesses. The most frequent weakness is the lack of generality, as some representations are tailored to a particular type of application and express a particular view of the context. Additionally, there is a lack of a formal basis needed to capture the context consistently and support reasoning about its different properties. However, it can be concluded that context modeling using ontology is the best approach for context modeling due to the advantages it offers compared to other representations. The evaluation findings presented in Strang and Linnhoff-Popien [19], based on six requirements, show that ontologies are the most expressive models and fulfill most of their requirements.

1.1. Purpose of study

Our study focuses on new concepts in ambient intelligence, such as context-sensitive computing, the Smart Hose, defining user context, and various methods for representing context. Our goal is to propose a model for context information in a Smart Hose environment, which will support disabled individuals in their homes. We aim to develop a specific ontology for this domain, drawing upon existing ontologies such as the SOCAM project [20], the CoOL ontology, and SOUPA [21], while making necessary adaptations to meet our requirements.

2. METHOD AND MATERIALS

In our work, we have used ontology to modularize context-awareness in smart homes to represent the different contexts that a smart home can operate in (e.g., "sleeping", "entertaining guests", and "cooking dinner"). These ontologies could then be used to guide the behavior of the smart home's various devices and systems, allowing them to automatically adjust their settings and operations based on the current context. For example, if the smart home's ontology indicates that the current context is "sleeping", the lights might automatically dim, the temperature might be lowered, and any noise-producing devices might be turned off. Additionally, the use of ontologies could enable more complex reasoning about the context of the smart home, such as inferring the current context based on the actions of the occupants or anticipating future context changes based on scheduled events.

Also using ontology in smart homes aids in modeling the different roles and relationships between the different entities in the home, such as the occupants, their devices, and the physical spaces within the home. This could be used to enable more personalized and fine-grained control over the smart home's devices and systems, by taking into account the specific needs and preferences of different individuals. For example, an ontology could be used to represent the fact that a specific individual is the primary cook in the home, and as such, they should have priority control over the kitchen appliances.

Additionally, ontologies can be also used to model the physical spaces and objects in the home, and the relationships between them. This could be used to enable more intuitive and natural interactions with the smart home, for example, by using natural language commands to control devices based on their location within the home.

Moreover, using ontology to model the context of smart homes can also provide a semantic layer that can be used to enable interoperability between different smart home devices and systems, by providing a common vocabulary and set of rules for describing the state of the home. This could also make it easier for third-party developers to create new applications and services for smart homes, by providing them with a well-defined and consistent model of the home's context.

Another idea for using ontology in smart homes could be to use it to model the different activities that take place within the home and the resources required for those activities. For example, an ontology could be used to represent the fact that cooking dinner requires the use of the stove, oven, and kitchen counter space. This information could then be used to automatically manage the availability of these resources, by ensuring that they are not in use when they are needed for the current activity.

Additionally, an ontology can be used to model the temporal aspects of the context of a smart home, such as the time of day, day of the week, and current weather conditions. This information can be used to optimize the energy consumption of the smart home, by adjusting the settings of devices and systems based on the current time or weather.

Furthermore, using ontology for context-awareness in smart homes can also provide a means for the home to learn from the patterns of behavior of its occupants, by keeping track of the context of past events, and using this information to make predictions about the context of future events. This can be used to optimize the performance of the smart home, by anticipating the needs of its occupants in advance.

In summary, using ontology to model the context of a smart home can provide a powerful tool for enabling more intuitive and intelligent control over the home's devices and systems, by providing a consistent and comprehensive model of the home's context that can be used to guide the behavior of the home.

3. RESULTS

3.1. Generic ontology for representing context information

In context modeling, the importance of different types of context in context modeling and how a flexible context model design can allow for domain-specific concepts. Location, User, Activity, and Computational entities are identified as crucial contextual entities to capture context information in an intelligent environment, as they not only form the foundation of the context but also provide clues to related information. The context model is often divided into sub-domains, which enables the reuse of general concepts and provides a flexible way to define domain-specific knowledge. The context model is structured by a set of abstract entities, each describing a physical or conceptual object, along with a set of abstract subclasses. The upper ontology represents the general characteristics of basic contextual entities, while the specific ontology defines the details of general concepts and their characteristics in each sub-domain.

Context modeling is an important aspect of creating intelligent environments where applications and services can adapt to the user's needs and preferences. However, not all types of context are considered equally important in every domain. For example, in a smart home, location and activity are likely to be more important contextual entities than in a car navigation system.

Location, user, activity, and computational entities are identified as crucial contextual entities because they are often the foundation of the context and provide useful clues to related information. For example, a user's location can provide information about the environment they are in, which can affect the types of activities they may be engaged in.

To create a flexible context model, the context is often divided into sub-domains, which allows for the reuse of general concepts and the definition of domain-specific knowledge. For example, a location model for car navigation and a smart home service may share common concepts, such as spatial relationships between locations, which can be modeled with a general context model with specific variations.

The context model is typically structured by a set of abstract entities, each describing a physical or conceptual object, such as a person, activity, computing entity, or location, along with a set of abstract subclasses. These entities are linked to their attributes and relationships, which allow for the hierarchical structure of the subclass entities and the addition of specific concepts in a particular domain.

Finally, the context model is often divided into two levels: the upper ontology and the specific ontology. The upper ontology represents the general characteristics of basic contextual entities, while the specific ontology defines the details of general concepts and their characteristics in each sub-domain. This approach provides a way to create a flexible and extensible context model that can be adapted to different domains and applications.

Fig 2 shows a partial serialization of the ontology in OWL.

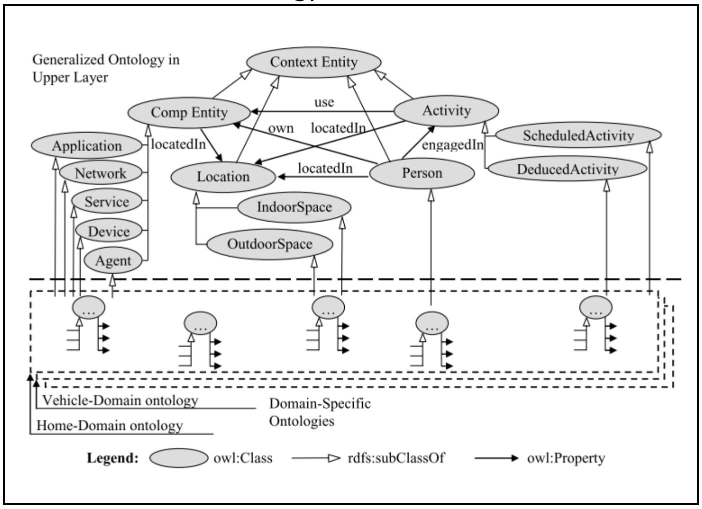

Fig. 2. Example of a high-level context ontology from the SOCAM project

Another proposed ontology for context modeling is called SOUPA (Standard Ontology for Ubiquitous and Pervasive Applications), expressed in OWL language. Like the SOCAM project, SOUPA consists of two sets of ontologies:

- SOUPA Core: defines the general vocabulary for various ubiquitous computing applications.
- SOUPA Extension: defines additional concepts used in specific applications.

While these models capture general concepts of context and provide reasoning about context, they are not specific to the domain of home assistance for disabled people and smart homes, which requires adaptation or development of new ontologies for this domain.

3.2. Development of our ontology

Our ontology aims to model context in a smart home environment for the assistance of disabled individuals. To achieve this goal, we have focused on managing the following daily tasks:

-Controlling the home environment (windows, doors, etc.).

An alarm system to monitor the home:

Fire alarm

-Gas leak alarm

-Accident or fall alarm for the user.

-Reminding the person of medication based on their health condition.

-Sending reminders to the person according to their status.

-Turning on lamps based on the presence of the user and intelligently managing the lighting, for example turning off lights in sunlight.
-Adjusting the air conditioning and temperature of the home based on the user's needs.
-Detecting the person's movements and falls, and sending an alarm to their assistant based on their situation:
If connected to the Internet, the system sends an email.
-If it is disconnected the system sends an SMS message.
− (If the person has fallen and is not moving, call emergency services).

3.2.1. The proposed smart hose system

Our proposed smart home system includes a central controller, which connects to a variety of sensors, devices, and systems throughout the home. These might include:

-Environmental sensors: These sensors would be used to gather information about the temperature, humidity, light, and other environmental factors in the home.

-Location sensors: These sensors would be used to gather information about the location of the devices and systems in the home, and the location of the occupants within the home.

-Occupancy sensors: These sensors would be used to gather information about the presence and identity of the occupants in the home.

-Smart devices: These devices would include things like lights, thermostats, appliances, and other devices that can be controlled and monitored remotely.

-Smart systems: These systems would include things like security systems, energy management systems, and other systems that can be controlled and monitored remotely.

-Communication devices: These devices would be used to enable communication between the hub, sensors and devices, and other systems, such as mobile devices, other smart home devices, or cloud services.

-Ontology engine: This component would be used to model the context of the home, by representing the relationships between the different entities in the home, such as the occupants, their devices, and the physical spaces within the home.

-Reasoning engine: This component would be used to infer new knowledge from the sensor data and context information, by using the ontology's axioms and rules.

-User interface: This component would be used to enable the occupants to interact with the smart home, by providing them with a way to control the devices and systems, view sensor data, and receive alerts and notifications.

-Data storage: This component would be used to store the sensor data, ontology, and other information related to the smart home system. This could include a triple store, graph database, or RDF database.

-Data pipeline: This component would be used to process, integrate, and store the sensor data, by using a data pipeline that includes a data lake or data warehouse to store the raw sensor data, then using a data integration tool to extract, transform, and load the data into the ontology.

-Machine learning engine: This component would be used to analyze the sensor data, context information, and ontology, using machine learning algorithms to extract relevant information, make predictions, or classify the data.

-Data visualization: This component would be used to display the sensor data, context information, and the ontology, in an easy-to-understand format, using tools such as ontology visualization tools, dashboards, or mobile applications.

-Security and Privacy: This component would be used to ensure the security and privacy of the smart home system, by implementing security mechanisms such as encryption, authentication, and access control, and by complying with data privacy regulations.

By integrating these components, the smart home system can gather information from the sensors, reason about the context of the home, and adjust the devices and systems accordingly, to provide the occupants with a more convenient, comfortable, and safe living environment.

In summary, the smart home system is a complex system that integrates various sensors, devices, systems, and software components to gather information about the context of the home, reason about it, and adjust the devices and systems accordingly to provide the occupants with a more convenient, comfortable and safe living environment. Additionally, the smart home system should also ensure the security and privacy of the home and the data it handles. Also, many additional components can be added to a smart home system to provide additional functionality and convenience, such as scheduling, rule-based engines, reporting, maintenance, and integration with other systems. These additional components can further enhance the capabilities of the smart home system, and provide the occupants with a more comprehensive and personalized living experience.

The first step in the development life cycle of an ontology is the needs assessment, in this step, we must specify:

− The operational objective of the ontology:

It is the use of this ontology in a multi-agent system for the assistance of disabled people in a smart home environment.

− The knowledge domain to be modeled:

It is the modeling of the user's context knowledge in a smart home environment.

− Potential users:

Who is the person with the disability, his assistant, and the doctor in charge of following him? After a thorough study of the numerous works interested in the development of a smart home environment, the smart home environment that we propose for the assistance of disabled people consists of a room containing all the devices and sensors necessary to ensure the assistance of disabled people in their homes.

This room includes a lamp to provide sufficient lighting throughout the room and also has a heater, air conditioner, and a TV with favorite channels.

The set of sensors installed in this chamber are the following:

− A luminosity sensor.
− A sensor for detecting the existence of the user using an RFID tag (radio frequency identification).
− A temperature sensor.
− A fire detection sensor.
− A sensor for gas leak detection.
− A sensor for the detection of accesses

The room is also equipped with an alarm system that monitors the environment and the user's actions and sends alarms to the assistant:
− An alarm in case of smoke
− An alarm in case of a gas leak
− An alarm in case of an accident or fall of the user

To ensure the management of appointments and reminders to take medication, the system has an agenda containing all the information and the time of taking each medication plus other necessary reminders. This agenda is installed on the user's PC and connected to his smartphone to send alarms and reminders.

The people involved in the system are the following:
− The person with a disability: Any person with a disability, physical or mental impairment [7].
− His assistant: any person in charge of the follow-up and the control of the health of the disabled person
− The doctor in charge of the medical follow-up of the disabled person. The functionalities that must be provided by the system are the following:
– The room temperature must be maintained within a given range. If the room temperature is too high, the system must intervene to set the air conditioner to an appropriate temperature.
– When a user approaches the room, the lamp must be turned on. For this purpose, the presence sensors located in the room identify the presence or not of a person.

3.2.2. Modeling ontology with UML

The second step of the ontology development cycle concerns the conceptualization of the domain's concepts in a conceptual model. In this step, the knowledge domain is described using more or less precise concepts and the relationships that may exist between these concepts. For this reason, we used the UML class diagram to represent the different concepts and the relationships between these concepts.

The following concepts can be identified (in the model using English terms):
▪ Lights
▪ Air-conditioner
▪ Heating
▪ Room
▪ Television set
▪ Person
▪ DisabledPersone
▪ Doctor
▪ Assistant
▪ Agenda
▪ Drug

▪ MedicalAlert
▪SmartPhone
▪ PC
▪ Alert
▪ FireAlert
▪ GazAlert
▪ AcedentAlert
▪ Sensor
▪ LightSensor.
▪ RFIDSensor.
▪ TemperatureSensor.
▪FireSensor.
▪ GazSensor.
▪ AccedentSensor.

In the UML class diagram, these concepts are modeled by classes where each class takes the name of a concept and its attributes represent the information about this concept.

3.2.3. Modelling of context information

After studying various upper-level ontologies, such as SOCAM, CoOL, and SOUPA, that model contextual information, we have determined that the Location, User, Activity, and Computational entities are the most fundamental entities for capturing context information in an intelligent environment. These entities inherit from the ContextEntity, which represents the basic context information.

The following properties can be considered in the model:
LocateIn: This relationship assigns a physical entity or person to a location in the environment.
Activity: The relationship between the Actor class and the Activity class defines the current activity of the actors.
Passage: The relationship between the Activity class and the Device class defines the devices used in an activity
ActivateAccidentAlert: The relationship between the AccidentSensor class and the AccidentAlert class models the action of triggering an alarm in case of an accident involving a disabled person.
ActivateMedicalAlert: The relationship between the Agenda class and the MedicalAlert class models the action of triggering a reminder to take medicine.
AlertAccident: The relationship between the AccidentAlert class and the Assistant class models the information of the assistant being alerted of the disabled person's accident.
GetContextInformation: The relationship between the Device class and the Sensor class models the retrieval of context information by the devices installed in the environment from the sensors.
Give medication: The relationship between the Assistant class and the DisabledPerson class models the assistant giving medication to the disabled person.
Medication: The relationship between the DisabledPerson class and the Medication class defines the list of medications taken by the disabled person.

MedicalDescription: The relationship between the Doctor class and the DisabledPerson class models the delivery of medication by the physician to the disabled person.
RememberMedicalTake: The relationship between the MedicalAlert class and the DisabledPerson class models the reminder for the disabled person to take medication.
Take medication: The relationship between the disabled person class and the Medication class models the disabled person taking medication.
Treat: The relationship between the Doctor class and the DisabledPerson class models the doctor's control and diagnosis of the disabled person.

Fig. 3 below represents the class diagram.

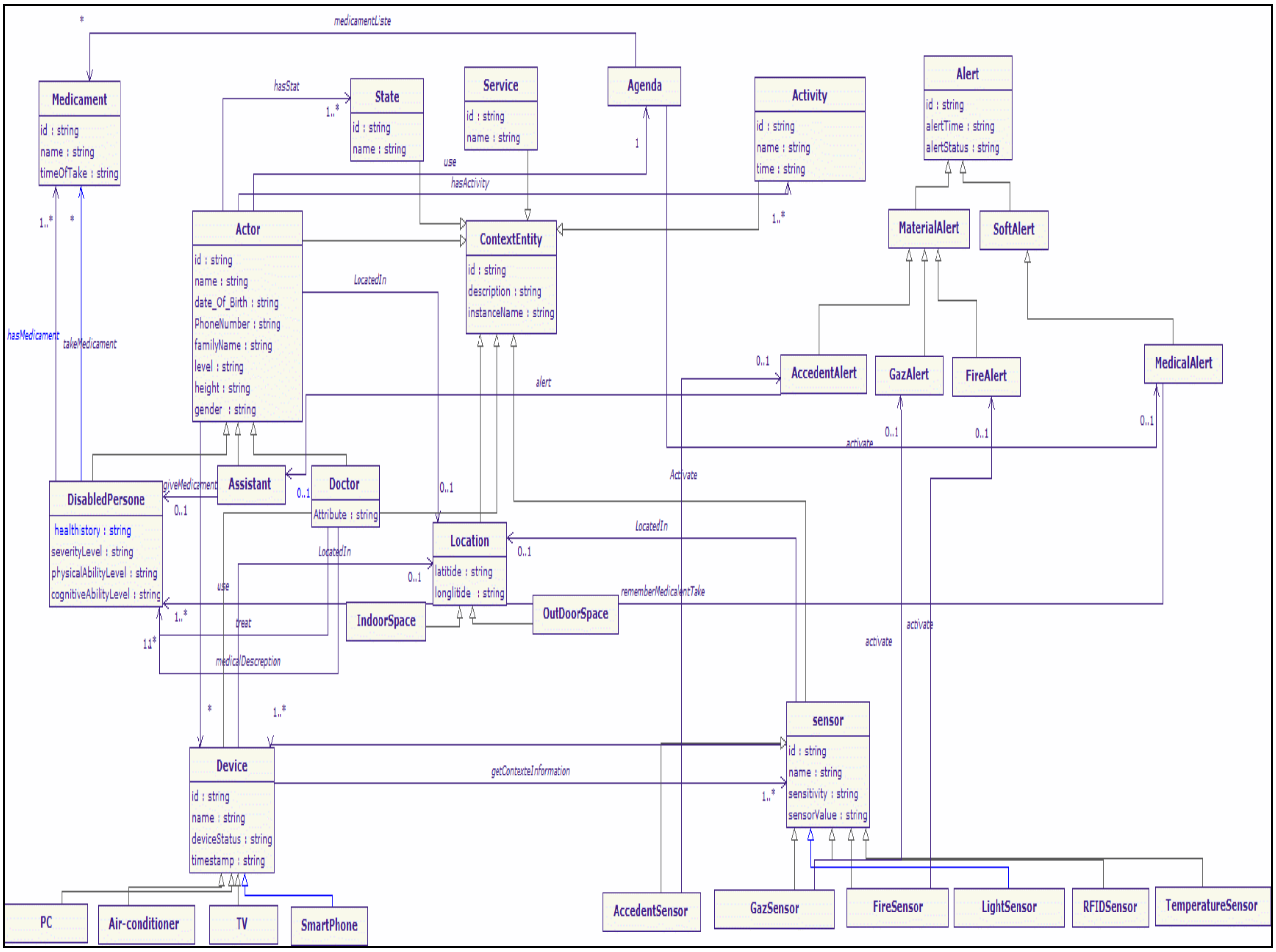

Fig. 3. represents the class diagram.

3.2.4. Formalization of the ontology

This step represents the third step in the ontology development life cycle. It involves the explicit and formal representation of the conceptualization obtained in the previous step using formal language. In our formalization, we used OWL (Web Ontology Language), the standard proposed by W3C for ontology representation.

3.2.4.1. Identification of Ontology Classes:

A class defines a group of individuals that share similar characteristics, referred to as the "class extension". Each individual in this group is known as an "instance" of the class.
From the UML class model, we can define new classes for our ontology, which are represented in the following Fig 4:

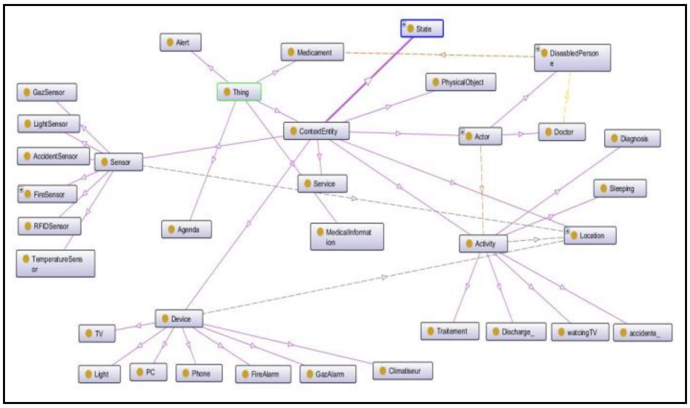

Fig 4. The context information modeling ontology

All these classes are subclasses of the superclass 'Thing', which is the parent class for all other classes.

3.2.5. Ontology class's declaration

The declaration of a class is made using the 'class description' mechanism, which has different forms. For instance, the 'Medicament' class is declared as follows:

```
<Declaration>
    <Class IRI="#Medicament"/>
</Declaration>
```

The inheritance relationship between classes is defined using the 'subClassOf' property. For example, the inheritance relationship between the 'Activity' class and the 'ContextEntity' class is declared as follows:

```
<SubClassOf>
    <Class IRI="#Activity"/>
    <Class IRI="#ContextEntity"/>
</SubClassOf>
```

3.2.6. Definition of ontology properties

In our ontology, properties serve the purpose of expressing facts about classes and their instances. OWL distinguishes between two types of properties: object properties and datatype properties. Object properties are used to connect instances to other instances (fig 5), while datatype properties are used to connect individuals to data values. The owl: ObjectProperty class is an instance of object properties, while the owl: DatatypeProperty class is an instance of datatype properties. Both of these classes are subclasses of the RDF class rdf: Property.

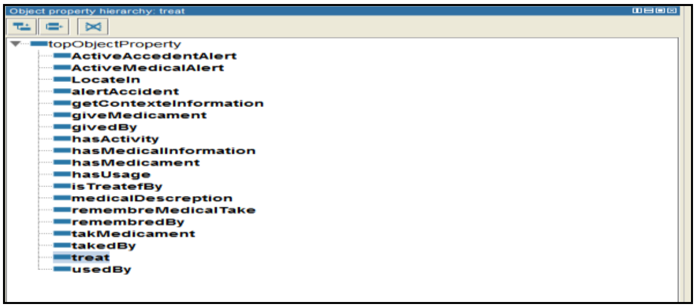

Fig 5. Object properties of the ontology

➢ LocateIn

```
<Declaration>
    <ObjectProperty IRI="#LocateIn"/>
</Declaration>
```

3.2.7. Characteristics of object properties

An object property can have several characteristics that significantly enhance the quality of reasoning related to this property. Some of the main characteristics include transitivity, symmetry, anti-symmetry, reflexivity, and functionality. Adding a characteristic to a property in the ontology is done using the specific OWL tag for that property definition. For example, with the LocateIn property:

```
<TransitiveObjectProperty>
    <ObjectProperty IRI="#LocateIn"/>
</TransitiveObjectProperty>
```

The object properties in our ontology are directly derived from the relationships in the UML class diagram and enhanced with the necessary features to support reasoning about the ontology (fig 6). The data type properties are derived from the attributes of the classes in the UML diagram:

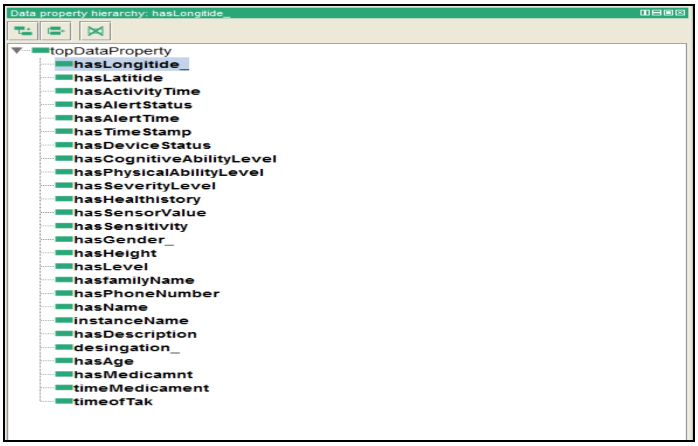

Fig 6. Ontology type properties.

4. CONCLUSION

Our research investigates innovative ideas in ambient intelligence, such as context-sensitive computing, Smart Home technology, and techniques for context representation to develop a context model for assisting disabled individuals in their homes. We aim to create a specific ontology for this domain by building on existing ontologies, such as SOCAM and CoOL, which capture general context concepts. In this work, we have adapted these generic ontologies for ambient intelligence and smart homes to support people with reduced mobility and the elderly in carrying out their daily activities without constant assistance from others. To further our research, we plan to test this ontology either in a real Smart Home environment or through simulations using virtual sensors.

In addition, we intend to integrate a context-based reasoning mechanism into our ontology by employing both ontology-based reasoning and rule-based reasoning approaches. This will enable us to reason about the context and make intelligent decisions based on the user's needs and preferences. Overall, our research is focused on creating a context model for Smart Home environments that is tailored to the specific needs of disabled individuals. We believe that this work has the potential to significantly improve the quality of life for this population, and we are excited to continue exploring new ways to enhance their living experiences through ambient intelligence.

In future work, we hope to test the developed ontology in real Smart Home environments or simulations using virtual sensors. This testing will help to validate the effectiveness of the ontology in assisting disabled individuals in carrying out their daily activities. Also, the Integration of a context-based reasoning mechanism into the ontology: into this ontology using both ontology-based reasoning and rule-based reasoning approaches. This will enable the ontology to reason about the user's context and make intelligent decisions based on their needs and preferences.

REFERENCES

[1] Q. Badar, & A. Anvari-Moghaddam, "Smart home energy management system–a review," *Advances in Building Energy Research*, vol. 16, no. 1, pp. 118-143, 2022, https://www.tandfonline.com/doi/abs/10.1080/17512549.2020.1806925.

[2] R. Hervás, O. Baños, & C. Villalonga, "Ambient intelligence for self-care and self-management," *Journal of Ambient Intelligence and Humanized Computing*, vol. 14, no. 1, pp. 1-3, 2023, https://link.springer.com/article/10.1007/s12652-022-04474-9

[3] Pise, B. Yoon, & S. Singh, "Enabling Ambient Intelligence of Things (AIoT) healthcare system architectures," *Computer Communications*, vol. 198, pp. 186-194, 2023, https://www.sciencedirect.com/science/article/pii/S0140366422004170

[4] K. H. Almotairi, "Application of Internet of things in healthcare domain," *Journal of Umm Al-Qura University for Engineering and Architecture*, vol. 14, no. 1, pp. 1-12, 2023, https://link.springer.com/article/10.1007/s43995-022-00008-8.

[5] G. Rong, A. Mendez, E. B. Assi, B. Zhao, & M. Sawan, "Artificial intelligence in healthcare: review and prediction case studies," *Engineering*, vol. 6, no. 3, pp. 291-301, 2020, https://www.sciencedirect.com/science/article/pii/S2095809919301535.

[6] K. E. Alhajaj & I. A. Moonesar, "The power of big data mining to improve the health care system in the United Arab Emirates," *Journal of Big Data*, vol. 10, no. 1, pp. 1-33, 2023, https://journalofbigdata.springeropen.com/articles/10.1186/s40537-022-00681-5

[7] M. Iwashita, K. Ishida, & M. Ishikawa, "Effect of User Personality on Efficacy of a Mental Support System Based on Ambient Intelligence: A Case Study," *Frontiers in Computer Science*, vol. 3, p. 702069, 2021, https://www.frontiersin.org/articles/10.3389/fcomp.2021.702069/full

[8] E. M. Onyema, S. Dalal, C. A. T. Romero, et al., "Design of intrusion detection system based on cyborg intelligence for security of cloud network traffic of smart cities," *Journal of Cloud Computing*, vol. 11, no. 1, pp. 1-20, 2022. https://journalofcloudcomputing.springeropen.com/articles/10.1186/s13677-022-00305-6

[9] B. Wang, H. Zhou, G. Yang, X. Li, & H. Yang, "Human digital twin (HDT) driven human-cyber-physical systems: Key technologies and applications," *Chinese Journal of Mechanical Engineering*, vol. 35, no. 1, p. 11, 2022, https://link.springer.com/article/10.1186/s10033-022-00680-w.

[10] T. Dujardin, J. Rouillard, J.C. Routier, J.C. Tarby, et al., "Intelligent management of a smart hose context by a multi-agent system," Proceedings of the Journées Francophones sur les Systèmes Multi-Agents, 2011.

[11] S. A. Jain, M. R. Patil, & R. K. Choudhary, "Context-Aware Computing: A Survey," *Journal of Ambient Intelligence and Humanized Computing*, 2021.

[12] Z. Zeng, X. Zhang, L. Wang, & Y. Liu, "Towards Context-Aware Recommendation in IoT: A Survey," Journal of Network and Computer Applications, 2021.

[13] H. Alhazmi & M. Alomari, "Context-Aware Mobile Services: A Systematic Review of Research Directions," Journal of Mobile Information Systems, 2020.

[14] M. Alomari, H. Alhazmi, & R. Alrajeh, "Context-Aware Systems and Applications: A Survey," Journal of Mobile Information Systems, 2019.

[15] J. C. Augusto, M. J. Quinde, C. L. Oguego, & J. Giménez Manuel, "Context-aware systems architecture (CaSa)," *Cybernetics and Systems*, vol. 53, no. 4, pp. 319-345, 2022, https://www.tandfonline.com/doi/abs/10.1080/01969722.2021.1985226.

[16]C. Bettini, O. Brdiczka, K. Henricksen, J. Indulska, et al., "A survey of context modelling and reasoning techniques," *Pervasive and mobile computing*, vol. 6, no. 2, pp. 161-180, 2010, https://www.sciencedirect.com/science/article/pii/S1574119209000510.

[17]R. Delgardo, R. Blasco, A. Marco, et al., Agent-based AmI System Case Study: The Easy Line+ Project. 2010, http://glyndwr.repository.guildhe.ac.uk/207.

[18]D. N. Mekuria, P. Sernani, N. Falcionelli, & A. F. Dragoni, Smart home reasoning systems: a systematic literature review. *Journal of Ambient Intelligence and Humanized Computing*, vol. 12, pp. 4485-4502, 2021, https://link.springer.com/article/10.1007/s12652-019-01572-z

[19]T. Strang, & C. Linnhoff-Popien, "A context modeling survey," In Workshop Proceedings, Sept. 2004, https://elib.dlr.de/7444/.

[20]D. Nawara & R. Kashef, "Context-aware recommendation systems in the IoT environment (IoT-CARS)–A comprehensive overview," *IEEE Access*, vol. 9, pp. 144270-144284, 2021, https://ieeexplore.ieee.org/abstract/document/9583301/

[21]J. Pierson, "A context information management infrastructure for ambient intelligence," Ph.D. thesis, Université Joseph Fourier - Grenoble 1, 2009.