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User Context Ontology for Adaptive Mobile-Phone Interfaces

MUHAMMAD WASEEM IQBAL[1], NADEEM AHMAD CH[2], SYED KHURAM SHAHZAD[3], (Member, IEEE), MUHAMMAD RAZA NAQVI[4,5], BABAR AYUB KHAN[5], AND ZULFIQAR ALI[6]

[1]Department of Software Engineering, Superior University, Lahore 54000, Pakistan
[2]Department of Computer Science, University of Sialkot, Sialkot 51013, Pakistan
[3]Department of Informatics and Systems, University of Management and Technology, Lahore 54500, Pakistan
[4]INP-ENIT, University of Toulouse, 65000 Tarbes, France
[5]Department of Computer Science, Superior University, Lahore 54000, Pakistan
[6]Department of Computer Science, National University of Technology (NUTECH), Islamabad 44000, Pakistan

Corresponding author: Muhammad Waseem Iqbal (waseem.iqbal@superior.edu.pk)

ABSTRACT The Adaptive User Interface (AUI) adapts to the changes in the context of use and provides improved interaction abilities for different users. The adaptivity in the user interfaces requires in depth knowledge of context. There is a need to enrich user profiles to achieve the personalized services with the ability to adapt the user's context. The context can be reflected in a particular kind of knowledge and hence modeled as ontology. Ontology based context models are effective means to handle complex situations that support the sharing or integration of context information. This paper presents ontology based context model using OWL for adaptive mobile devices. It models the context over its four major elements including device, user, environment (location and time) and activity. The proposed ontology was derived in different classes, relationships, associations, dependencies and constraints to model dynamic context. Ontologies present a standardized, consistent and shareable context model. The context model and consequent context snapshots can be acknowledged by AUI to present a suitable user interface. The ontology was developed using Protégé on the basis of each context type having different values. Semantic querying (SPARQL) was used for knowledge acquisition. Moreover, the Pellet and HermiT Reasoner were used to verify the rules, relations and constraints to avoid the inconsistency between classes. Comparative to other context models for adaptive interfaces, ontological model provides more of scalability and growth with learning new context in to the shared context knowledge.

INDEX TERMS Adaptive user interface, context aware interface, ontology driven interfaces, knowledge representation, knowledge engineering.

I. INTRODUCTION

The Adaptive User Interface (AUI) is personalized by the computer without direct user's intervention and usually requires automated intelligent decisions [1]. Such adaptive personalization can be performed more often without consuming the user's time and energy [2]. The AUIs support automatic adaptability whereas the human computer interaction tends towards adaptive behaviors that allow the users to customize interfaces [3], [4].The AUIs have been known for more than a decade for providing context fitting interfaces for computer devices. Still there are very limited interface models presented to handle the context variety in an intelligent manner [5]. The context-aware systems are capable to adapt their operations for current context without unambiguous intervention of user. It is desirable that interfaces may adapt their behavior when circumstances change rapidly according to context. The required information can be retrieved by using the status of device, information of network, applying of sensors, user profile browsing or other sources [6]–[8]. Furthermore, the context is any information that can be used to describe the situation of an entity related to interaction between application and user [9]. It is not easy to count the important aspects of all situations that will change according to conditions and circumstances. Some contextual information such as localization, time, date and nearby people is needed to interpret something in context [10]. The comprehensive context modeling becomes much difficult due to

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diversity in different life styles and individual or collective needs of users. There is a need to enrich user profile to achieve the personalized services with the ability to a user's context [11].

The current state of the art provide many semantic and ontological model developed as lower ontological model for specialized environment and context. The researchers have used the ontological modeling and knowledge representation techniques for the formal modeling of various domain and application concepts for better information retrieval, visualization, analysis and interaction design [12]–[15]. The research under discussion is targeted for a flexible and scalable middle level ontology for an adaptive user interface development. The ontology engineered generalized all variants of devices by a device concept, user details by user concept, geo-spatial dimension and other environmental elements by environment concepts. The ontology aims to provide a shareable standard context structure to extend the knowledge-base by new sub-concepts or materialization through each context experience. It is a part of an intelligent interface development and adaptation research through User Centered Design (UCD) approach, currently, focused on mobile-phones interface.

The paper is organized into VI sections, next section illustrate research problem, scope and objective. The section III provides the literature review and the extracted the user context, usage environment, context elements and ontological representation of context from current state of the art. Section IV demonstrates the research methodology in terms of ontology engineering for user context, story boarding, use case scenarios, vocabulary, taxonomy, semantic relations, constraints, verification through Reasoner and SPARQL queries. Section V discusses the results generated through reasoning tools and querying the defined use case scenarios. Conclusion and future work is presented in the last section.

II. PROBLEM STATEMENT

The current situation of the user is normal as well as critical information that eventually leads to an evaluation of user's preferences. For example, user might be "driving a car" and the context changes all the time. Likewise, the situation "taking selfie" is the user context where mobile phone usage cannot change during certain time interval [16]. The variability of actions and displays helps to read the user context and makes the interface more adaptable.Ontology based context models are effective means for sharing and integration of context information [9], [10]. A user context ontological model can be developed on the basis of user's characteristics such as personal information, skills, preferences and personalized services [17]. Generally, human understanding and conceptualization differ depending on diversity in situations. It is required to define these concepts through inference rules or semantic relations or classes on ontology for computational purpose [18]. Recently, variety of user interaction styles and modes of mobile devices add complexity in their user interfaces [19], [20]. In the last few years, research on user profiling and context has been encouraged the development of adaptive systems that are to be used by heterogeneous users [21]. The personalization is a focused concern on the detailed level, whilst there are many generalized context element structures that can be addressed in interface designing and modeling phases prior to personalization and interface instantiation. User interface adaptation methodology can be assisted by the knowledge of the context values and respective interaction design. There exist many semantically enriched context aware interaction and information modeling and designing approaches [12]–[15]. The semantic and ontological modeling is intended to provide a shared, formal concepts for as knowledge that can be linked, aligned, reuse and grow through evolution. In this regard, ontological modeling of user profiles is generally application specific and created for specific domain or task. These solutions have provided adaptable user interfaces for specific contexts. They are lacking in intelligent decision making, automatic switching to the respective mode and learning new contexts. An adaptive interface needs to be a smart solution that can learn new contexts, sense existing contexts and modify itself according to any unknown context. Formal ontology is a method to develop such context knowledge-base [22]. It has ability to keep all the context picture consistent, standardized, shared and scalable [23]. The ontology intended also used the previous knowledge to render few concepts reuse or generalize. As for instantiation of the adaptive user interface, the Mobile-Phone interfaces are the test subject of the research. Thus, by considering the issues, some competency questions are defined to develop user context ontology for adaptive mobile phone interfaces.

- CQ1. How usage of context can be formally defined for mobile-phones?
- CQ2. What are the context properties affecting mobile-phone interfaces?
- CQ3. What are the user properties affecting mobile-phone interfaces?
- CQ4. What are the device properties affecting mobile-phone interfaces?
- CQ5. What are the environment properties affecting mobile-phone interfaces?
- CQ6. What are the activity properties affecting mobile-phone interfaces?
- CQ7. How different context properties are related semantically?

This paper presents a context based ontological model using Web Ontology Language (OWL) for adaptive mobile devices. It models user's context, device parameters, environment (location and time) and activity. Classes and sub-classes have been created for the given parameters to establish the relationships between these concepts. The proposed ontological model is needed to preserve context in terms of context elements and concepts forming these elements. It also captures the relationship, dependencies and constraints among the concepts forming the context. It is also needed to have the reflection of context model to respective adaptive interface through their semantic relations and computable mapping functions. In the larger perspective, this research is part of User Centered Design (UCD) approach for adaptive user interface design and development [24]. The major goal of UCD is to offer optimized, efficient and user friendly products which increase the usability and satisfaction of users [4], [25], [26].

III. LITERATURE REVIEW

The literature studied considering two major aspects of the research including identification of the context factors effecting interaction design and secondly the ontological information modeling of user context and user interface elements. The study presented in 2009 by Hartman showed that the Microsoft Office hidden smart menus in prior versions (Pre-2007 version) were affected by many usability issues. But the menus contained predefined adaptive parts (e.g. display the most recent used items) in its revised version-2007 which seemed to have more advantages for users [4]. Likewise, Dostál et. al developed boulevard, a fine-grained adaptive user interface, for OpenOffice.org writer word processor. In this study 12 participants were engaged in which 9 were males and 3 were females, aged from 21 to 53 years (M=28.75 years). In qualitative measures, users were able to select their desired commands in cases of toolbars, menus and boulevard during first attempt around 62.7 percent, 53.3 percent and 66.4 percent respectively. But users failed to select command during 30 seconds (maximum time) in 20 cases for toolbar, 67 cases for menus and 11 cases for boulevard part of experiment [27]. In 1999, Dey et al stated that context can be used to define the position of an entity. The study described the four context types and three context-aware features of the applications. The selected systems contain different applications of context-aware behavior. For example, cyber guide, context toolkit, active badge, NETMAN and augmentable reality have context types (identity, location) and context-aware types (presentation and tagging) [22]. Open Service Gateway Initiative (OSGi) provided secure service delivery and reliable remote management of context aware mobile services. The SOCAM middle ware was developed to provide the support to context-aware systems on the top of OSGi. For implementation purpose, the ontologies of vehicle domain were developed consisting 19 classes and 30 properties. Context interpreter validated and parsed OWL expressions into Resource Description Framework (RDF) triples while context query received [28]. The sensor based context ontology for mobile device was derived with the combination of different sensors implanted in a mobile device. The ontology supports the rapid mobile applications development, usage of resources efficiently, knowledge re-usability and information sharing between communicating entities. The concept of ontology driven prototyping was proposed for the display of adaptive information [29]. In 2011, Shahzad et al discussed ontological modeling approach for Graphical User Interfaces (GUIs). The end result was User Interface Model UIM described as RDF/XML files containing the tags of domain ontology and User Interface Ontology (UIO). It was evident that user interfaces properties and their relationships can be defined through semantic and ontological framework as UIO [30]. Different ontologies have been developed in different contexts but still there is need to create ontology for mobile devices in user's context. The CC/PP (Composite Capabilities/Preference Profile) is a W3C initiative model that proposed an infrastructure to express the preferences of user and capabilities of device. It can be used to guide the content adaptation presented to the device. The CC/PP is profiles based architecture which uses RDF language for implementation. It consists of a hierarchical structure of components which is divided into three areas such as hardware, software and application [31]. CoBrA-ONT (Context Broker Architecture) defines some of the common attributes and relationships related to places, people and activities. The main objective of this ontology is to enable knowledge sharing and ontology reasoning within the CoBrA [32]. The CoDAMoS ontology is used to solve the challenges of automatic code generation, code mobility, application adaptation and generation of device specific user interfaces. It defines four main core entities such as user, environment, platform and service [33]. CONON (Context Ontology) determines the general concepts about person, location, activity or computational entity, whose terms are thought to be extensible in a hierarchical way by adding domain specific concepts. This specific ontology captures the generic features of basic contextual entities [34]. The Delivery Context Ontology provides a formal model of the environment characteristics in which different devices interact with concrete services. The major entities modeled in this ontology are hardware, software, environment and location. SOUPA (Standard Ontology for Ubiquitous and Pervasive Applications) is designed and model to support pervasive computing applications. It is divided into SOUPA-Core, which defines such concepts that appears in many scenarios (e.g. time, person, space) and SOUPAExtensions that supports specific concepts in narrower domains (e.g. office, home) [32] [35]. DOLCE upper level ontology was developed within the WonderWeb project. It showed that how DOLCE used Onto-Clean methodology and understood some major WordNet's semantic limitations [36].

A. USER CONTEXT AND USAGE ENVIRONMENT

Variable regarding user's environment are already available in previously defined ontologies providing knowledge in many dimensions demography, cognitive skills, background, education, personality and preferences. The different users interpret the command names, icons and displays in different ways which is one of the major challenges in Human Computer Interaction (HCI) research [37]. The context and task define the change that needs to be performed in response to the specific movement at the user interface [38]. In mobile computing, the context-awareness or physical environment includes surroundings of a user and device (e.g. location and time) [7], [36]. Context modeling for usage learning has been defined into three categories such as:

- Based on domain knowledge
- Supervised learning approaches
- Unsupervised learning approaches.

Supervised learning approaches require a serious amount of domain knowledge while unsupervised learning does not require domain knowledge [39], [40]. It is very difficult to collect relevant information about the causes of usability hindrance from users. This issue may create difficulties for application developers to develop adaptive applications according to user's contextual information [27].

B. CONTEXT ELEMENTS

The defined context elements are represented through semantic relations and their constraints [34]. In our model the contexts are dynamic that are extracted from environment which help to identify the situation of a user at certain time or location. Actually a ''situation'' is a complex notion that may be seen at different granularity. In our research, the user context has been considered as a set of parameters such as device, user, environment and activity. Context adaptation by user interface can be done in two broad approaches (i) static context adaptation is user-driven (customization) in which contents are provided and controlled by user principally (ii) dynamic context adaptation (personalization) is not user driven in which user is essentially inactive or has less control [41]. In ontologies, the context information is mostly represented in static form of adaptation while dynamic characteristics are still needed to be incorporated. Though an ontology permits the existence of multiple instances of classes that may change with the passage of time [5] (e.g. living conditions of user). There are plenty of ontologies developed previously to specify user contexts focusing on user properties only. There are also ontologies modeling the environment in different application areas. The devices and machines are defined in their respective ontologies. The combination of these context elements needed to be presented to form a whole context of mobile-phone usage for user interface adaptivity. The following are the aspects of ontological model to context adaptation for mobile users.

1) DEVICE CONTEXT

Devices are used in various kinds of situation which changes dynamically according to particular context change. Small screen size, display, mobility, sensor, capacity, processor, memory, graphics, input and output functionalities affect the usage of interfaces and interaction [40]. The device should be smart enough to understand the user's needs, make decisions based on the read context and proceed with adequate actions without interrupting the user [42], [43].

2) USER CONTEXT

User's context may contain demographic information (e.g. name, age, country, city, state, gender, education) and be able to represent the preferences of either a group of users or a single person. User profiles are generally represented as sets of weighted keywords, semantic networks, or weighted concepts, or association rules. User's willingness and time are required for the development of a personal profile [16], [30], [44], [45].

3) ENVIRONMENT CONTEXT

The environment context has four major types such as (i) physical (ii) social (iii) virtual and (iv) computational environment. The precision and concentration of environment context knowledge depends at the sensing abilities of the application and device to sense the environment such as weather, temperature, noise, time and location [46]–[48].

4) ACTIVITY CONTEXT

User modeling is required to maintain and update the user's profile while task modeling refers to particular user's activities to infer further information. A user's activity may have a specific location, time and context [17]. The activity context is used to describe information about the users, tasks and goals [34].

C. ONTOLOGICAL REPRESENTATION OF CONTEXT

The formal ontology has capacity to communicate information and the ability to represent entities to name the concepts in machine readable form. It can also define these concepts in different classes and specific instances. Humans have concepts, based on knowledge cognition including system devices, senses, experiences and context [49]. These concepts are abstract, vague, composite or real. Humans create mental models and expect system and device behavior accordingly. All automated systems comprise of software and hardware provide computational models of real world concepts. Ontologies are used to express these concepts formally to define a computational model. Ontology driven information systems approach is being used to design the application in human's perspective [22]. Thus, we are exploiting the benefits of ontologies to formally state the usage context of adaptive user interfaces. The anticipated ontology may be composed of representational terms for the elements of the mobile usage context. This type of ontology needs to represent association amongst entities in the universe of discourse (e.g. classes, relations, functions, objects or constraints) with human readable text description.

IV. ONTOLOGY ENGINEERING FOR USER CONTEXT

Ontology engineering is used to develop ontology to formally define the concepts of usage context in detail. The context elements can be read and understood by any machine or computational system with these formal definitions stated in OWL/RDFs.

A. USE CASE (UC) SCENARIOS

Some trial scenarios are built for different contexts in smartphone usage. Mobile Phone is a sample device used in this

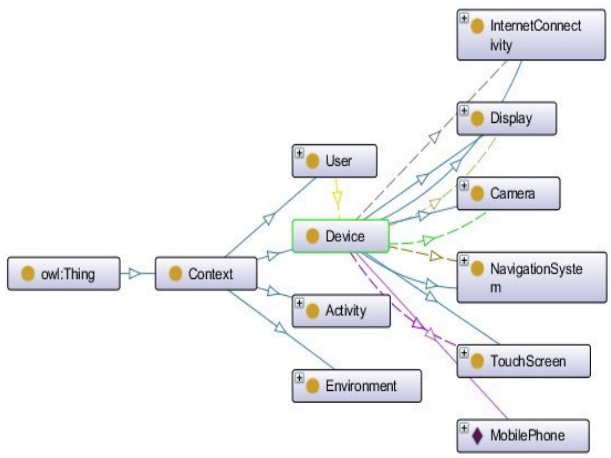

FIGURE 1. Device taxonomy.

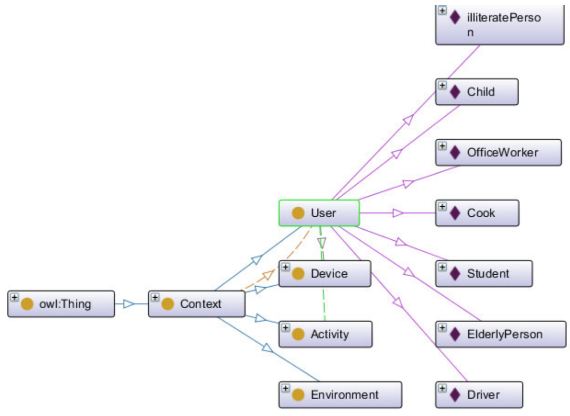

FIGURE 2. User taxonomy.

research; it is selected due to variety of functions and usage environments such as official applications, entertainment videos or geospatial services etc. These scenarios are built for different categories of users, environment and activities using different tasks (e.g. child is taking selfie in park at night, office worker attending a meeting in morning at office, illiterate person using mobile-phone on roadside at noon, driver is prohibited to take selfie during driving etc.).

1) A child is taking selfie in the park at night.
2) An office worker is attending meeting in morning at office.
3) An illiterate person is searching nearest hospital over the web at noon on roadside.
4) A driver is using navigation system in garage in morning.
5) A cook is using web-services in kitchen at noon.

B. VOCABULARY

The vocabulary constitution for ontological model is presented in Tab.1. This vocabulary is constructed over the recognized elements of context especially considerable for interface design. These elements are identified by many of the past research work performed in last three decades and discussed in the literature review section [28], [29], [33], [46], [50]–[52].

C. TAXONOMY

The taxonomy of relevant concepts are extracted from mentioned literature and published ontologies [31]–[35]. The taxonomy development is performed as the second step after vocabulary building for ontology engineering. The Table.1 has provided all the concepts with initial relations of classes and subclasses along with data and object properties. The taxonomy was developed using Protégé (version 5.2.0). The hierarchy is formed on the basis of each context type having different values of the dimension like user, activity, time, location (classes, instances, properties). Semantic queries will be used for knowledge acquisition while the knowledge sharing is accomplished through the instances of concerned branches of context tree [29] There are four basic concepts of context properties such as user, environment, device and activity. These concepts are the base classes of context taxonomy.

1) DEVICE TAXONOMY

Device taxonomy is elaborated in Fig.1 where device properties provide the device context as part/kind of whole context class. The properties are made according to the sample scenario requirements. Camera: object property and DisplayColor: data properties are examples of the device properties. The individuals/instances for the scenarios include MobilePhone, TouchScreen, InternetConnectivity etc.

2) USER TAXONOMY

Fig.2 shows the user taxonomy in which user properties provide the user context as part/kind of whole context class. The properties are made according to the sample scenario requirements. HasDevice:object property and Age: data property, are examples of the user properties. The individuals/instances for the scenarios include OfficeWorker, Driver and Child etc.

3) ENVIRONMENT TAXONOMY

Environment taxonomy is described in Fig.3 where environment properties provide environmental context as part of whole context class. The properties are made according to the sample scenario requirements. HasLocation: object property and HasTime: data properties are examples of the environment properties. The individuals for the scenarios include RoadSide, Gym, Garage and Morning etc.

4) ACTIVITY TAXONOMY

Activity properties provide the activity context as part/kind of whole context class which is shown in Fig.4. The properties are made according to the sample scenario requirements. HasTouch: object property and DisplaySize: data property are

TABLE 1. Vocabulary representation for ontological model development.

Class	Subclass	Object Property	Data- Property	Instances
Context	User, Device, Activity, Environment			
Device	Camera, Display, Internet Connectivity, Navigation,System, Touch screen	hasCamera, has Display, hasInternetConnectivity, hasNavigationSystem, HasTouchScreen	Camera Quality, Display Color, Display Size, Screen Size	Auto Brightness, Back Camera, Front Camera, High Brightness, Low Brightness, Maps, Mobile Internet, WiFi, Mobile Phone, Touch Screen
User	Child, Driver, Cook, Office Worker, illiterate Person		hasAge	Child, Driver, Cook, Office Worker, illiterate Person
Environment	Location, Time	HasLocation, HasTime		Office, Park, RoadSide, Kitchen, Garage, Gym, Morning, Noon, Night
Activity	Meeting, Searching Nearest Petrol Pump, Searching Nearest Hospital, Taking Selfie, UsingWeb services, Workout			Meeting, Searching Nearest Petrol Pump, Searching Nearest Hospital, Taking Selfie, UsingWeb services, Workout

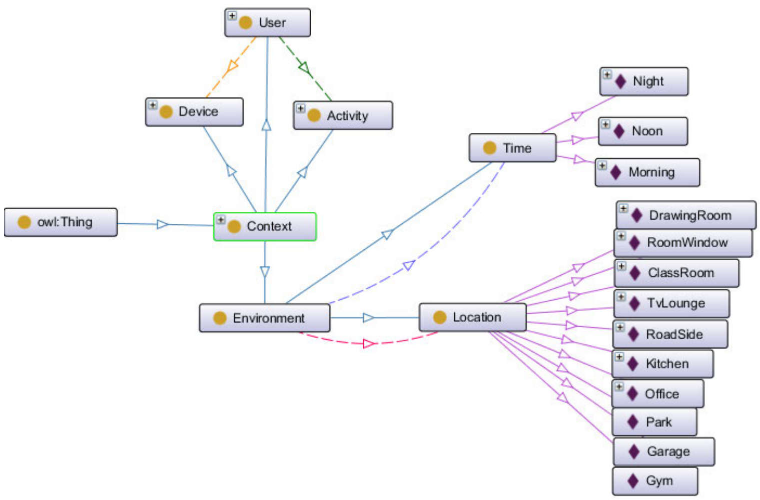

FIGURE 3. Environment taxonomy.

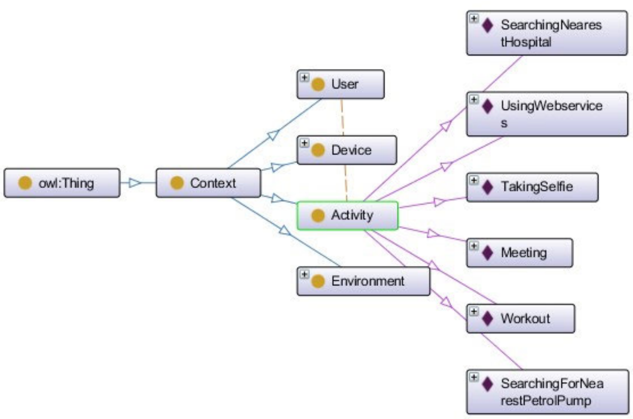

FIGURE 4. Activity taxonomy.

examples of the task properties.The individuals/instances for the scenarios includeWorkout,,TakingSelfie,etc.

5) SEMANTIC RELATIONS

The concept of semantic relations is shown in Fig.5 where these relations are defined according to the user requirements of selected scenario. Here each concept has its semantic relations within the developed taxonomy.

6) CONSTRAINTS OF SCENARIOS

The defined constraints are applied on different individuals allowing them to be in a relation with specific range of values.Some Use cases are having different constraints discussed below.

- As an example from the exercised scenario, the individual child has constraints over the age, location and activities. In Fig.6 the given scenario shows that child HasLocation: Park, HasActivity: TakingSelfie, HasDevice: MobilePhone, HasTime: Night and HasAge: 15. The constraints are shown that child HasActivity: Meeting, Workout, SearchingNearHospital, Kitchen,

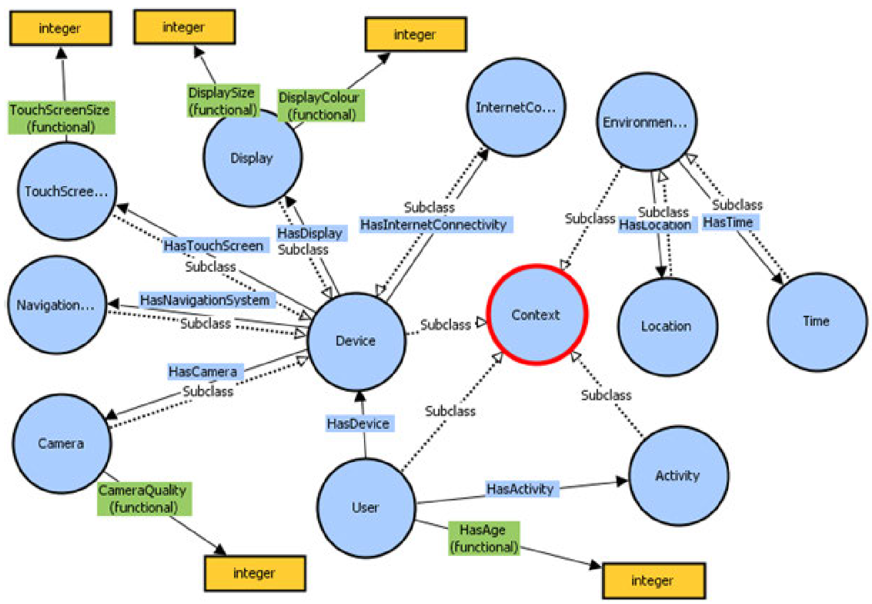

FIGURE 5. Semantic relations.

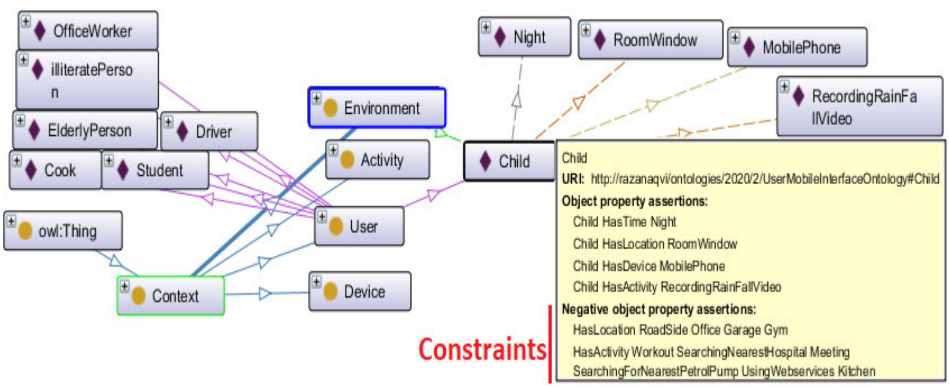

FIGURE 6. Semantic constraints.

UsingWebServices, SearchingForNearestPetrolPump and HasLocation: Office, RoadSide, Garage, Gym.

- The scenario of OfficeWorker is discussed in Fig.7 along with its constraints. OfficeWorker HasTime: Morning, HasActivity: Meeting, HasLocation: Office, HasDevice: MobilePhone and Has age: 35. The constraints are shown that OfficeWorker HasTime: Night, HasActivity: SearchingNearHospital, SearchingForNearestPetrolPump, TakingSelfie, UsingWebServices and HasLocation: Kitchen, Garage, Park, RoadSide.
- The scenario of OfficeWorker is discussed in Fig.8 along with its constraints. The properties of IlliteratePerson are shown in Fig.8 as: HasDevice: MobilePhone, HasLocation: RoadSide, HasActivity: SearchingNearestHospital, HasTime: Noon and Has age: 30. The constraints are shown in this scenario that IlliteratePerson HasActivity: Meeting, UsingWebServices, SearchingForNearestPetrolPump, Workout, TakingSelfie and HasLocation: Office, Gym, Park, Garage, Kitchen.

7) VERIFICATION THROUGH REASONER

Specifically, reasoning over rules is monotonic with addition of new piece of observation cannot change already inferred knowledge. There is a strong relationship between context modeling and reasoning to produce effective and efficient results [53]. However, the proposed ontological model is derived for non-monotonic rules in which dynamic observation can be treated. Validation Protégé provides third-party Reasoner like HermiT and FaCT++ and others to validate the ontologies [54]. Reasoner detects and finds inconsistencies or contradictions of ontologies structure and data based on mathematical models [55]. It provides logical deductions based on inference rules defined and specified in description logic and uses forward chaining or backward chaining to perform inference [56]. Pellet Reasoner is used to validate our ontology model. Previously researchers and ontology engineers use reasoner to validate their work [57]–[59]. It can be used in unification with Jena and OWL APIs.Reasoner were used to verify the rules, relations and constraints to detect the

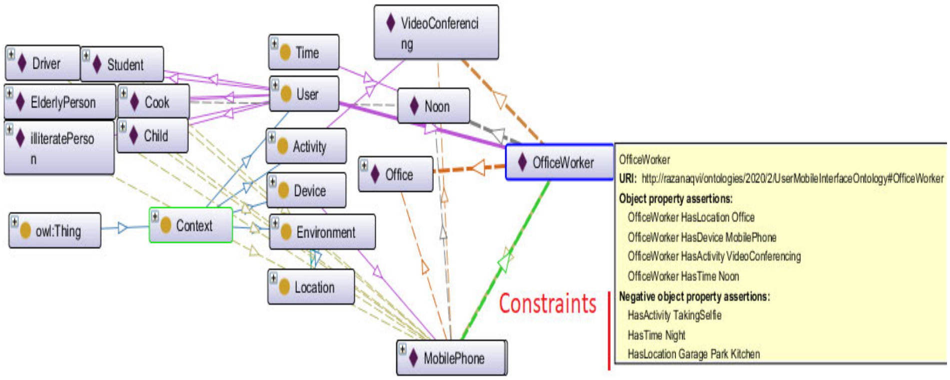

FIGURE 7. Semantic constraints.

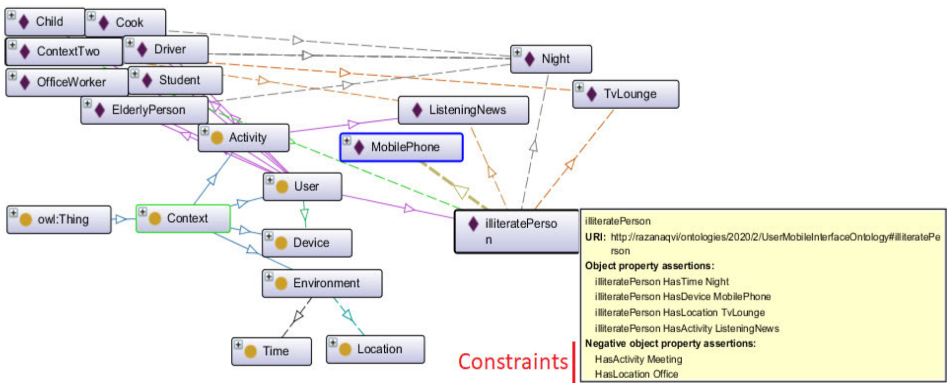

FIGURE 8. IlliteratePerson constraint scenario.

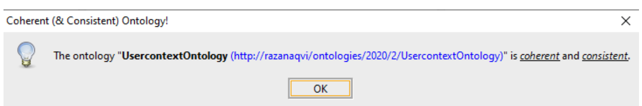

FIGURE 9. Validation of Ontology consistency and coherency using Pellet reasoner.

inconsistency among concepts definition and relations in the built ontology.

8) CONTEXT KNOWLEDGE REPRESENTATION THROUGH ONTOLOGY

The developed context ontology formally defines the usage context. It provides answer to the first competency question that requires a formal description for the usage context of smart devices. It consists of all the classes and individuals for the provided scenarios. These classes and individuals include Device, User, Environment and Activity properties that reflect the solution to CQ2 and sub-questions CQ2.1 to CQ2.4. This Ontology also preserves the semantic relations and constraints among defined classes and instances. With the provided results through consistency checking by the Reasoner, the suitable response to the CQ3 is also ensured in developed ontology. Furthermore, the ontology has been developed and verified through SPARQL query language. The OWL DL and OWL2 are ontology languages to capture the context of elements of interest (e.g. persons, events, activities, locations) and their appropriate relations by mapping the information to respective class properties [60]. SPARQL can be used to express queries across diverse data sources, optional graph patterns along with their conjunctions and disjunctions. SPARQL also supports aggregation, sub-queries, negation, creating values by expressions, extensible value testing, and constraining queries by source RDF graph. The results of SPARQL queries can be result sets or RDF graphs.[1] The sample sets of queries performed through SPARQL have been taken from the defined semantic

V. RESULTS AND DISCUSSION

Context has been defined and preserved in user context ontology with their semantics as individuals of given use case scenarios. These scenarios can be extracted using SPARQL. The Fig.9 to 13 provide the SPARQL queries of defined use case scenarios.The adaptive environment adjusts the operational and usage parameters according to the contexts. Adaptivity deals with automated processes which require reading the context and deciding about the operations of interaction model. Overall, the computation needs machine

[1]https://www.w3.org/TR/2013/REC-sparql11-query-20130321/

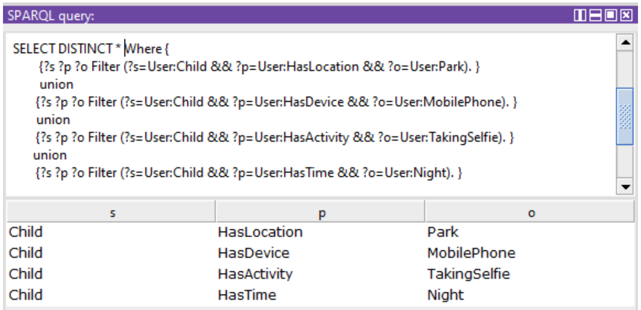

FIGURE 10. Use Case 1 description using context ontology.

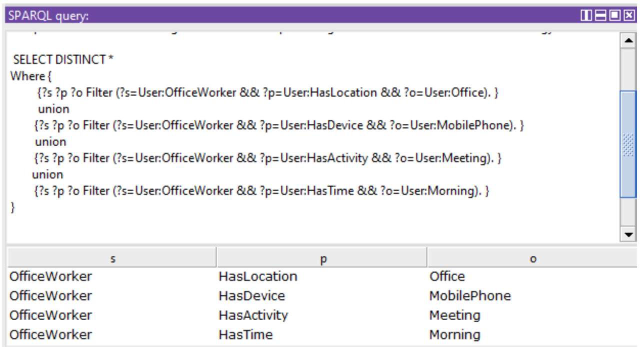

FIGURE 11. Use Case 2 description using context ontology.

readable and computable elements of contexts. The SPARQL queries have retrieved the context details that can be used in UCD for interaction style development of respective AUI e.g. the mobile interface of a driver, child or office worker etc.

The query, in Fig.9, extracts the information about use case scenario 1 where "A child is taking selfie in the park at night". The result shows that the subject "Child" along with the properties and objects provide relations like HasLocation: Park, HasDevice: MobilePhone, HasActivity: TakingSelfie and HasTime: Night.

In use case scenario 2, "An officeworker is attending meeting at day time in his office". The Fig.10 shows information that the subject "OfficeWorker" along with the properties and objects provide relations like HasLocation: Office, HasDevice: MobilePhone, HasActivity: Meeting and HasTime: Morning. The Fig.11 shows the result of description of using context ontology for use case scenario 3 where "An illiterate person is searching nearest hospital over the web on roadside". The result getting through given query shows that the subject "illiteratePerson" along with the properties and objects provide relations like HasLocation:RoadSide,HasDevice:MobilePhone, HasActivity:SearchingNearestHospital and HasTime: Noon.

The query given in Fig.12 extracts the information about use case scenario 4 where "A driver is using navigation system in garage in morning". The result shows that the subject "Driver" along with the properties and objects provide relations like he HasLocation: Garage, HasDevice: MobilePhone,

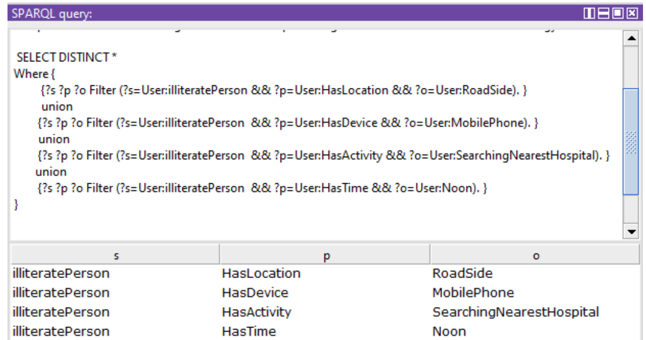

FIGURE 12. Use Case 3 description using context ontology.

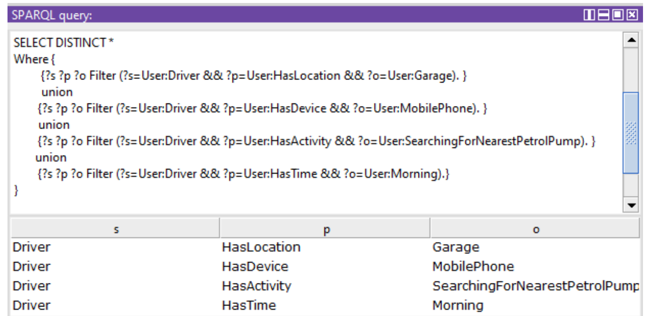

FIGURE 13. Use Case 4 description using context ontology.

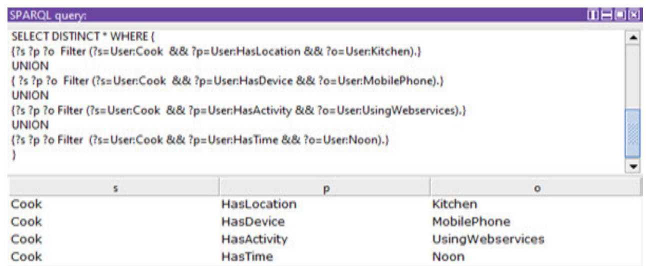

FIGURE 14. Use Case 5 description using context ontology.

HasActivity: SearchingForNearestPetrolPump and HasTime: Morning.

"A cook is using web-services in kitchen" representing use case scenario 5. The query given in Fig.13 shows the result that the subject "Cook" along with the properties and objects provide relations like cook HasLocation: Kitchen, HasDevice: MobilePhone, HasActivity: UsingWebservices and HasTime: Noon.

User context elaborated the details formally to facilitate adaptive user interfaces (AUIs) to define user interaction modes and styles accordingly. Selection of interaction can be done dynamically such as if it detects the use case 2 situation, the device may go to silent mode or any specialized settings for the context.

VI. CONCLUSION

Currently, there are millions of mobile phone users available globally due to the rapid adaptation of mobile computing. Excessive usability concerns of mobile phones have brought gigantic data collections of user preferences. User profiles, contexts, situations and description of semantics provide the basis for a demand-driven personalized information and service logistics. All these descriptions are based on hierarchical set of attributes that characterize an entity, instantiated as user profiles, situation profiles and service profiles. Sensors within the mobile devices gather context values of all users automatically and whenever a user significantly changes his or her context, the (new) situation is derived dynamically by the inference engine. Finally, the service matching provides all appropriate values of the user's context and profile, grouped into categories. AUI, with the consideration of user's updated value, updates the actual set of recommended services at the user's smart phone. All of this is done using semantic rules defined on the basis of different context dimensions e.g. device, user, task and environment. In current point of discussion, this semantic context model targeted to bring an adaptive usage environment. This research has concluded with a scalable, technology independent, and semantically verified shared context knowledge framework. Ontology here presents the reasoning base for intelligent adaptation in user interfaces. The targets achieved include the ontological context elements representation for interaction design that can be instantiated for while interface development. As the next step of major research, the resultant User Context Ontology(UCO)[2] will be used as input for intelligent Context to Interface mapping algorithms. The UCO enables us to populate the knowledge base through variations of interaction contexts beyond the device or usage specifications. This property will be exploited for knowledge discovery over context pattern and context-interface correlation identification. The resulting context knowledge, as future research directions, can be adopted for different mobile usage context mining, analysis and context aware systems with machine learning and AI algorithms.

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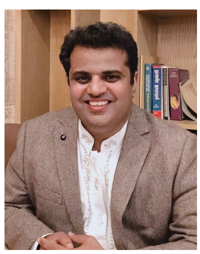
MUHAMMAD WASEEM IQBAL received the Ph.D. degree in human–computer interaction from the Superior College Lahore, Pakistan, in 2020. He is currently working as an Assistant Professor with the Department of Software Engineering, Superior College (University Campus), Lahore. He served as the Head of the Department of Software Engineering, Superior University Lahore, for three years. He has more than 15 years of teaching and research experience in well reputed institutions and has 30 research publications in multiple conferences and journals. He specializes in human–computer interaction (HCI), with special interest in adaptive interfaces for mobile devices in user's context. Further, he focuses in different research areas like usability evaluation of mobile devices for normal and visual impaired people, people centered interface, user context, semantic relations, and ontological modeling.



NADEEM AHMAD CH received the dual Ph.D. degree in human–computer interaction from the University of Potsdam, Germany, and Politecnico di Torino, Italy, in 2014. He works as the Pro-Vice Chancellor with the University of Sialkot, Pakistan, where he is involved in corporate planning. In the capacity of the Chairman, he served two years with the Department of Computer Science, Superior University, Pakistan. He also worked as the Head of the Department of Computer Science and IT, The University of Lahore, Pakistan, for three years. His research work mainly focuses on transforming society through digital technologies, natural user interfaces, healthcare informatics, data analytics, people centered interfaces, usability barriers, localization, accessibility, and visual design.

SYED KHURAM SHAHZAD (Member, IEEE) received the Ph.D. degree from the Knowledge Management Institute, Graz University of Technology, Graz, Austria, in 2012. He is a designated Assistant Professor with the School of Systems and Technology, University of Management and Technology, Lahore, Pakistan. His research interests include data and knowledge technologies, knowledge discovery from data, semantic, and ontological modeling, smart service integration, and collaborative systems. He has been a member of IEEE Computer Society Lahore Section, since 2017. He has arranged two IEEE conferences as a Conference Secretory and Publication Chair with technical support by IEEE Lahore section.

MUHAMMAD RAZA NAQVI received the Bachelor of Computer Science degree from The University of Lahore, Pakistan, and the master's degree in computer science from Superior University. He is currently working as a Research Assistant at INP-ENIT, Tarbes, France. He has been working in the area of knowledge technologies and cyber-physical systems. He has participated in the development of advance drug-drug ontology (ADDI), ontology driven health integration systems, ontology driven smart agriculture systems, and investigates, domain ontologies, upper-level ontologies, knowledge graphs, and data integration. Further, he focuses on block chain technologies and usability evaluation of smart phone in different domains for normal and visual impaired people in areas of human–computer interaction.

BABAR AYUB KHAN received the master's degree in computer science from Superior University (Gold Campus), Lahore, Pakistan, in 2020. He has more than six years of experience in professional technology sectors. He is currently engaged as the Managing Director of a multinational software company providing numerous web services named as 'Chimp Studio' operative currently from Lahore. Apart from the prior studies, he also emphasis in different research areas like usability evaluation of mobile devices for normal and impaired people, person-centered interfaces, the Internet of Things (IoT), and user context modeling.

ZULFIQAR ALI received the B.S. degree in computer science from Allama Iqbal Open University (AIOU), Islamabad, Pakistan, and the M.S. and Ph.D. degrees in computer science from the National University of Computer and Emerging Sciences (NU-FAST). He is currently working as an Assistant Professor with the Department of Computer Science, National University of Technology (NUTECH), Islamabad. His research interests include machine learning, data mining and knowledge discovery, data science, and evolutionary computing. He is currently working on classification, associative classification, and emerging pattern discovery using swarm intelligence techniques. He has several research publications in these areas.