# An ontology-based approach to support the development of adaptive interface systems

Alexandre Adler Cunha de Freitas[1], Monalessa P. Barcellos[1]

[1]*Ontology & Conceptual Modeling Research Group (NEMO), Computer Science Department, Federal University of Espírito Santo (UFES), Brazil*

**Abstract**

Advances in technology have introduced new challenges to ensure optimal usability for diverse users. Adaptive User Interface (AUI) systems offer a potential solution by dynamically adjusting the interface to the user. However, developing these systems is complex, requiring capturing user characteristics and preferences. This paper provides an overview of a doctoral proposal that proposes OADAPT, an ontology-based approach to support AUI system development. The approach comprises a knowledge framework about AUI systems (represented through networked ontologies) and a process that guides the steps to use the ontologies to develop AUI systems. OADAPT emerged from developing a social network called SNOPI, which automatically adapts its interface based on users' needs and characteristics, such as low vision and colorblindness.

**Keywords**

Adaptive User Interface, AUI System, Ontology, Ontology Network

## 1. Introduction

In the ever-evolving technological landscape, the development of interactive systems that prioritize human needs and preferences has become important. Designing these systems with a human-centered approach is crucial to their success [1]. As our digital society continues to advance, there is a growing demand for intuitive and user-centric interactive systems that cater to individual needs. This necessitates the creation of well-designed user interfaces (UI) that facilitate effective communication between users and the system.

Users differ in a wide range of variables, including demographic characteristics, educational background, personality traits, cognitive abilities, and personal preferences. Understanding these user differences is paramount for designing inclusive and user-centric systems, which requires employing user-centered approaches incorporating Adaptive User Interface (AUI) development. By embracing these approaches, developers can create systems that are accessible to different users.

Developing AUI systems is a complex and knowledge-intensive undertaking [2]. UI adaptations need diverse user information. Therefore, it becomes necessary to structure and organize knowledge about the user and the system to facilitate appropriate adaptations in the UI. In this work, we argue that using ontologies holds promise in addressing this challenge. Ontologies serve to capture and organize knowledge, enabling the structured representation of information about interactive systems and users' characteristics. By employing ontologies, we can gain a deeper understanding of how such systems function and utilize this knowledge as a foundation for structuring them. Furthermore, ontologies can help identify the necessary adaptations and support the implementation of mechanisms to enact these adaptations in real time.

In the literature, some works have explored the use of ontologies to develop AUI systems [3] (e.g., [4], [5], [6], [7], [8] and [9]). However, the ontologies often are very specific, i.e., they can only be used to solve a particular problem in the context of the system to which they were created, and are used mainly at the operational level. This may work for isolated solutions, but systems have been required to be

*Proceedings of the 17th Seminar on Ontology Research in Brazil (ONTOBRAS 2024) and 8th Doctoral and Masters Consortium on Ontologies (WTDO 2024), Vitória, Brazil, October 07-10, 2024.*

alexandre.a.freitas@ufes.br (A. A. C. d. Freitas); monalessa@inf.ufes.br (M. P. Barcellos)

0000-0002-6622-0722 (A. A. C. d. Freitas); 0000-0002-6225-9478 (M. P. Barcellos)

more comprehensive and constantly evolve according to the user needs. Isolated solutions are usually hard to be extended to incorporate new requirements or reused in the development of new solutions.

Therefore, we advocate that ontologies should also be used at the conceptual level to structure knowledge about the system and user characteristics. Thus, it is possible to provide a general knowledge representation that can be used as a basis to define UI adaptations and develop AUI systems. We also argue that, ideally, we should use ontologies from an ontology network (ON), i.e., a set of interconnected ontologies that provide a comprehensive conceptualization of the domain of interest and have a common global conceptual structure that helps share their concepts [10]. By doing so, it is possible to constantly evolve the set of possible adaptations by considering different concepts from the networked ontologies.

In view of the above, in this work, we build networked ontologies and explore them and others from an ontology network to help develop AUI systems at both conceptual and operational levels. As a result, we will propose an ontology-based approach to provide knowledge and guidance on how to develop AUI systems with the support of networked ontologies.

This paper presents an overview of the work and is organized as follows: Section 2 discusses *Related Work*; Section 3 describes the *Research Method*; Section 4 presents *Current State of the Research*; Section 5 summarizes *Next Steps*.

## 2. Related Work

Some works propose the use of ontologies in the development of AUI systems [3]. For example, Bonacin et al. [4] use a recoloring ontology to develop a functional web prototype that changes the colors of UI elements automatically for colorblind users. Braham et al. [5], in turn, use ontologies and UI design patterns to develop a mobile application that supports run-time adaptation of the UI for people with disabilities. In the work by Stefanidi et al. [7], ontologies are used to support the development of an AUI system aimed at improving users' situational awareness. Khan and Khusro [9] used an ontology to model and store concepts and relationships of an AUI system for visually impaired users on touchscreen devices. Sala et al. [8] used ontologies for annotations in an automated adaptation system to enhance the accessibility of public e-services. Fedasyuk and Lutsyk [6] propose an adaptive system to help people with cognitive disabilities and used an ontology to adapt the functionalities and graphical UI. All these works focused on the use of operational ontologies and did not follow a systematic process, which makes it difficult for other people to repeat the process to develop other systems.

Like in the works aforementioned, in our work, we propose to use ontologies to help develop AUI systems (specifically their software constituent). However, our proposal has some important differences. First, we argue for the use of well-founded reference ontologies, which are application-independent and, thus, can be used to develop different AUIs and different systems. Moreover, they can be translated into operational ontologies to be used at run-time. Second, we propose the use of ontologies of an ON. Thus, different ON extracts (i.e., ontologies containing different concepts) can be used to develop different systems. In addition, the set of user characteristics and other concepts represented in the ON can increase over time (because the ON continuously evolves) enabling one to address new adaptions. Finally, our proposal (i) provides structured knowledge, by means of networked ontologies, that addresses relevant aspects of adaptive systems and AUI to support AUI systems development, and (ii) describes the steps to be followed to use ontologies from an ON to develop AUI systems and. As a benefit, third parties will be able to use the proposed process and the knowledge to develop AUI systems.

## 3. Research Method

The methodological approach adopted in this work follows the Design Science Research (DSR) paradigm. DSR focuses on extending human and organizational capabilities through the creation of novel and innovative artifacts [11, 12]. It comprises an iterative process that encompasses three cycles: the *Relevance Cycle*, *Design Cycle*, and *Rigor Cycle* [11]. Several experimental studies will be carried out during the work. As suggested by Barcellos et al. [13], we organize the studies as *learning iterations*,

i.e., studies performed in iterations that allow the researcher to learn something about the research, by providing useful knowledge to understand the problem, develop the artifact, and evaluate or improve it. Figure 1 provides an overview of the Design Science cycles and learning iterations in this research.

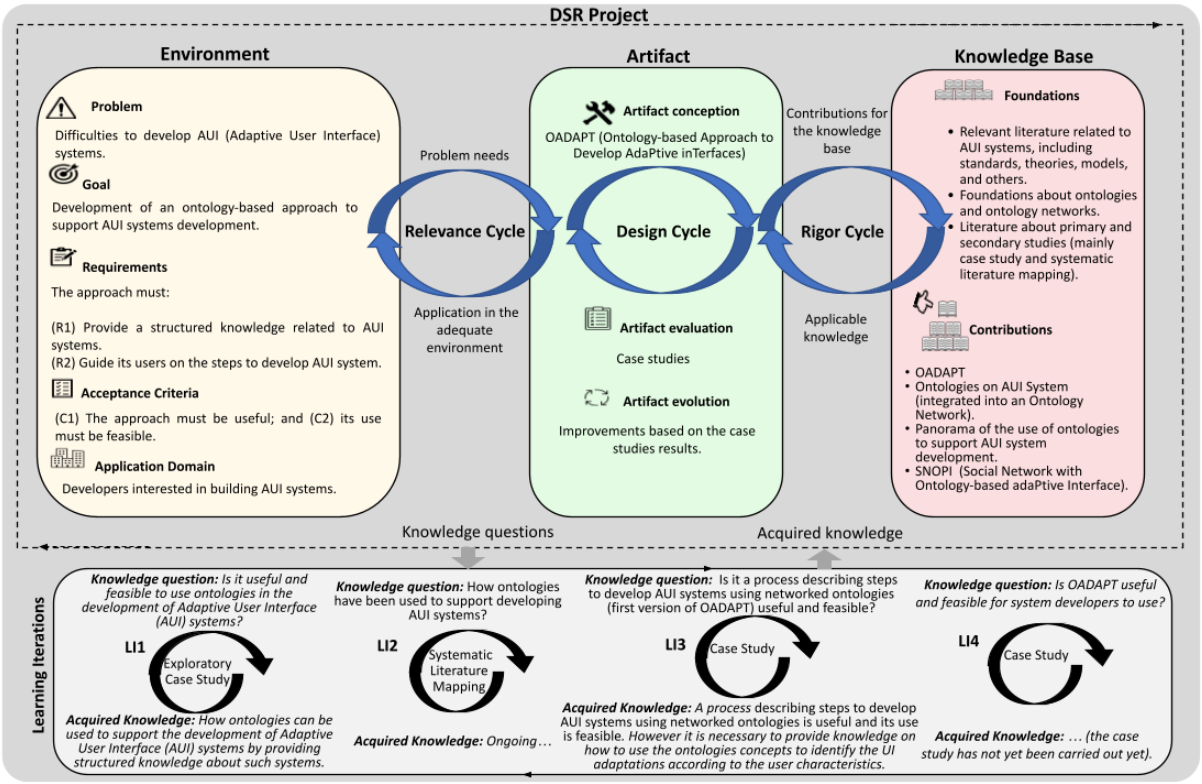


**Figure 1:** Overview of the Design Science cycles in this research (based on [11, 12]).

## 4. Current State of the Research

This work aims to explore the use of networked ontologies to support AUI systems development. The main artifact resulting from this work is an ontology-based approach to support AUI systems development. The approach must (R1) provide structured knowledge about AUI systems, and (R2) guide its users on the steps to develop AUI systems by considering the structured knowledge. Hence, we have developed OADAPT (*Ontology-based Approach to Develop AdaPtive inTerfaces*), which comprises (i) networked ontologies added to the Human-Computer Interaction Ontology Network (HCI-ON) [14] (to meet R1), and (ii) a systematic process (to meet R2).

The first version of the OADAPT resulted from an exploratory study in which we added ontologies to HCI-ON and used an HCI-ON extract to develop SNOPI (Social Network with Ontology-based Adaptive Interface) (for further information the reader must refer to [15] and [16]). SNOPI is a social network centered around academic subjects that automatically adapts its UI according to the needs of low-vision and colorblind users. After that, OADAPT was used in a case study to evolve SNOPI, producing SNOPI 2.0, which allows for gesture and voice adaptations [17].

Figure 2 shows an overview of the eight-step process of OADAPT. The process comprises eight steps, five of which are classic software development steps, while three focus on the use of ontologies to develop AUI systems.

Figure 3 shows a fragment of the knowledge component of OADAPT, i.e., networked ontologies from HCI-ON. HCI-ON structures knowledge in three layers: (i) *foundation layer*, containing UFO Guizzardi et al. [18], the Unified Foundational Ontology [18], which provides the basic concepts and common

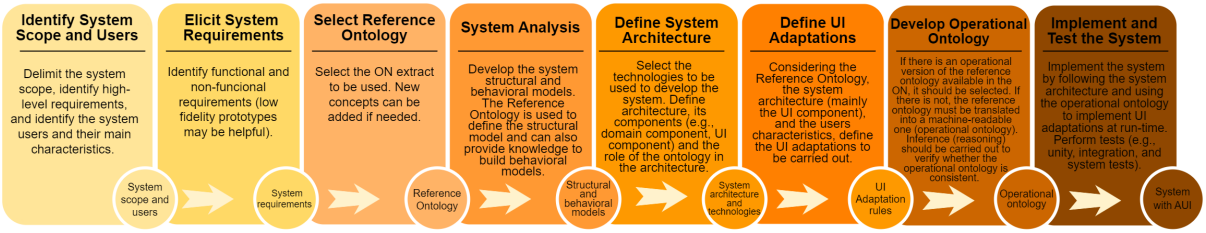


**Figure 2:** OADAPT process.

ground for all the networked ontologies; *core layer*, containing ontologies addressing HCI core aspects, such as user, interactive system and interaction; and *domain layer*, which encompasses ontologies addressing HCI subdomains, grounded in UFO or core ontologies. The ontologies developed in this work were integrated into the domain layer.

We have added to HCI-ON four new ontologies (under development): *Adaptive Interface Ontology* (AIO), *User Profile Ontology* (UPO), *User Characterization Ontology* (UCO), *UI Types and Elements Ontology* (UIT&EO). Figure 3 shows a fragment of HCI-ON including concepts from the ontologies developed in this work. Double red dotted lines separate the core and domain layers. Black dotted lines separate concepts from different ontologies. Different colors are used to designate different ontologies. For simplification, we omitted the foundation layer in the figure.

The ON fragment shown in Figure 3 was used to develop SNOPI. Figure 4 provides an overview of the SNOPI architecture. The UI layer contains the user interface components. The application layer handles system functionalities. The data layer manages data structure and storage. The semantic layer uses ontoSNOPI, the operational ontology that implements the ON extract used to develop the tool, along with rules to adapt the interface based on user characteristics and profile. SNOPI uses networked ontologies at the conceptual level to structure the system and at the operational level for reasoning about the adaptations according to the user profile and characteristics.

## 5. Next Steps

This paper presented an overview of a doctoral research that aims to explore the use of networked ontologies to support the development of AUI systems. An ontology-based approach called OADAPT has been proposed.

The results obtained so far are promising, but it is still necessary to refine the process to improve guidance, extend the networked ontologies to provide more comprehensive knowledge, and make the use of the ontologies' concepts to create the UI adaptation rules more explicit. Moreover, it is still necessary to evaluate OADAPT without the researcher's intervention (the first author was involved in the studies performed so far).

Therefore, as the next steps of this research, we plan to use Feature Models [19] to represent the necessary UI adaptations according to the user characteristics and profile; refine OADAPT process descriptions by providing examples based on SNOPI experience; extend the networked ontologies considering some needs already identified, and perform a case study to evaluate OADAPT without the researcher intervention.

## Acknowledgments

This research is supported by the Coordination for the Improvement of Higher Education Personnel - CAPES Brazil (Finance Code 001) and the Espírito Santo Research and Innovation Support Foundation - FAPES (Processes 2023-5L1FC, 2022-NGKM5, 2021-GL60J, and T.O. 1022/2022).

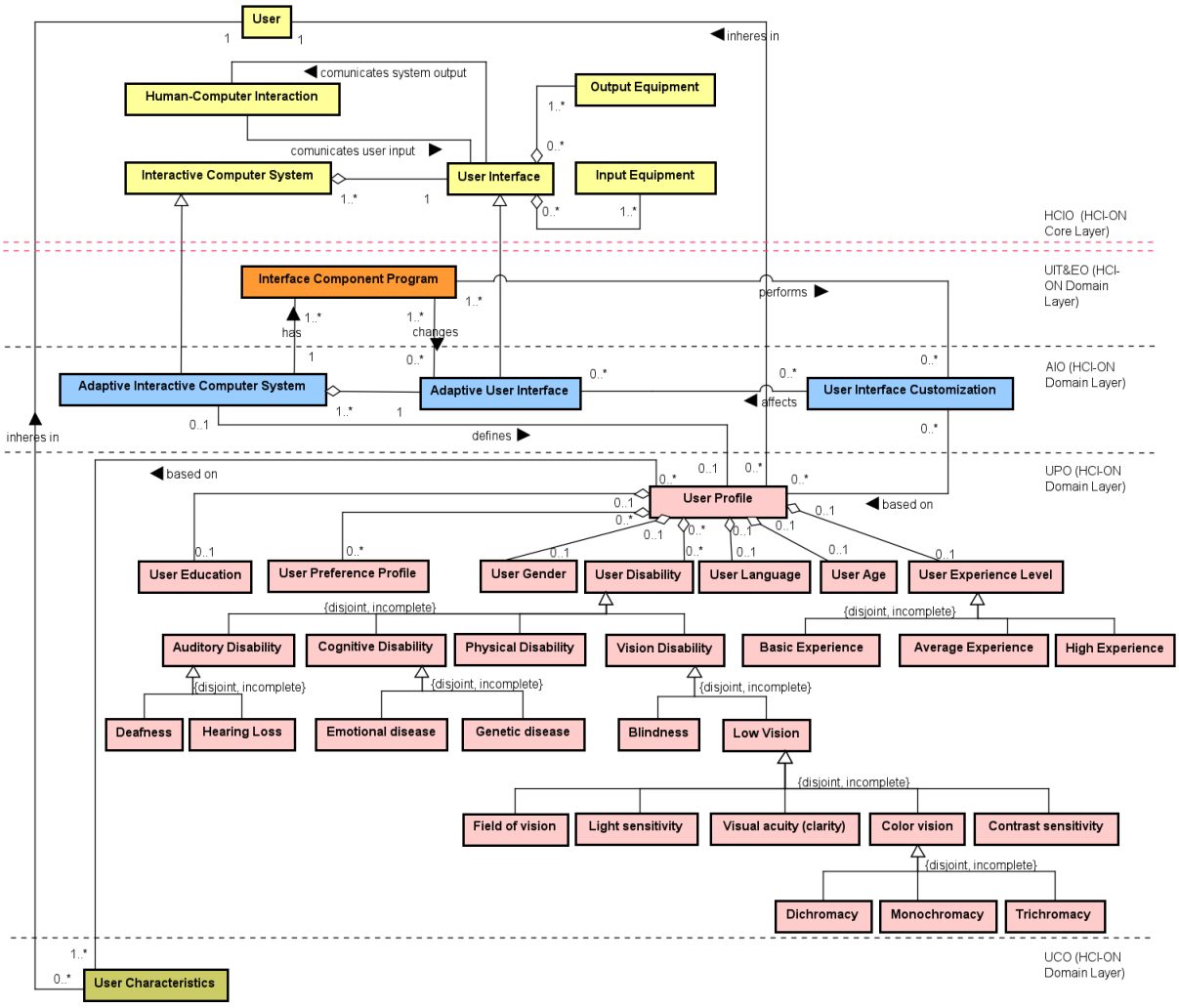


**Figure 3:** HCI-ON fragment involving AUI system concepts.

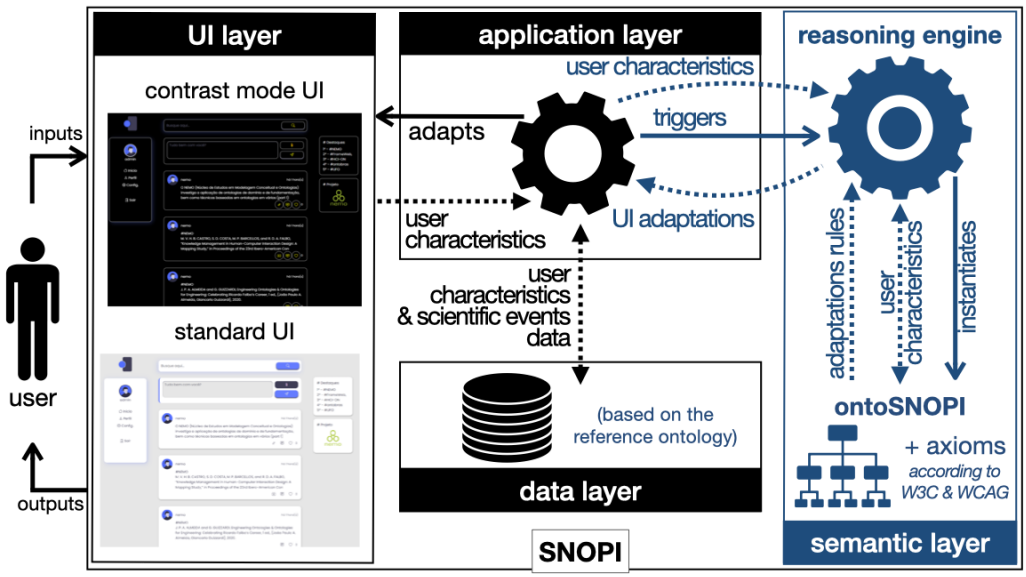


**Figure 4:** SNOPI architecture overview.

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