Enhancing User Experiences in Ubiquitous Soft Computing Environments with Fuzzy Agent Middleware

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Abstract

In the Ubiquitous Computing Environment (UCE) context, the successful provision of user-required services necessitates the collaboration of various system components, encompassing hardware parts, software components, and network connections. The utilization of UCE has presented some difficulties to customers seeking services in a diverse environment, including excessive Memory Usage (MU) and prolonged Component Construction Time (CCT). To optimize the user's experience, fuzzy agent employs a non-intrusive approach in online deep-rooted learning to get insights into user behavior. Integrating the advancements mentioned above aims to enhance the connectivity between users and information technology devices by utilizing an invisible network of UCE devices, creating dynamic computational environments that can effectively meet the users' needs. This work presents a unique methodology called Fuzzy Agent Middleware to Enhance User Experiences (FAM-EUI), which aims to improve user experiences in contexts where computer technology is seamlessly incorporated into everyday activities. This research endeavors to tackle the issues associated with imprecise data and enhance user-friendly interactions by integrating fuzzy logic with intelligent agents. The results highlight the potential of FAM in enhancing user interaction within ubiquitous soft computing, leading to improved efficiency and user-centered computing systems. This study provides valuable insights into integrating soft computing and agent-based technologies to enhance ubiquitous computing paradigms.

Keywords: Ubiquitous Computing, Fuzzy, Middleware, User Experiences, Intelligent Agents.

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1 Introduction

In recent years, there has been a significant increase in the pace of research on the UCE and the provision of services inside this context (Suma, D.V., 2021). There are two predominant lines of study in the field of ubiquitous services. The first stream investigates user context within the environment, while the second concerns developing service construction schemes. In the field of user context research, there is a predominant focus on exploring sophisticated techniques for acquiring the physical location of users and utilizing this information, together with their user profiles, to identify and provide suitable services (Symeonaki, E., 2020).

Service-building research strongly focuses on developing and evaluating advanced frameworks and schemes that provide dynamic collaboration across various system components. These components, referred to as entities in a ubiquitous environment, work together to deliver services tailored to the users' needs and preferences (Chang, K.C., 2020). The discourse around the practical implementation of ubiquitous services has mostly centered around two key areas: the remote management of household electronic equipment via portable devices and the development of information delivery systems that rely on user location data. In subsequent periods, users' expectations regarding these widely available services will transition towards more sophisticated applications, particularly those including multimedia communication services (Wan, J., 2013).

Ensuring adequate and comprehensive Quality of Service (QoS) that meets the demands of users is an inherent challenge in implementing ubiquitous services (Geihs, K., 2011). To effectively handle this issue, it is imperative to consider the user's context and the contextual factors related to hardware, network, and software resources. This phenomenon is because resource availability in ubiquitous environments is often characterized by inadequacy and volatility. Furthermore, solving the challenges associated with appropriate resource sharing and assignment is imperative when several users are concurrently provided with ubiquitous services.

The satisfaction of certain requirements and limitations, such as those related to network and computer resources, is crucial for the effectiveness of a ubiquitous environment. When considering the provision of rich services, such as multimedia communication services, in a ubiquitous environment, it is imperative to prioritize the consideration of QoS (Balasubramanian, V., 2021). For example, dynamic circumstances exist, such as user movement, the performance of devices near the user, and the state of available resources. Hence, it is plausible that devices close to the user may be unable to deliver the desired service owing to resource limitations, notwithstanding their potential for high performance. Furthermore, offering the service while considering the challenge of coordinating many unforeseen devices, software, and network components is important.

The prevalence of portable devices, such as laptops, smartphones, and personal digital assistants, is increasing among users. These devices are increasingly getting more advanced since they can support wireless technologies and application platforms. The rise of the UCE era has underscored the growing significance of user interaction middleware in facilitating user-centric services (Raghupathy, V., 2022). The proposed FAM-EUI aims to mitigate the effects of CCT and MU by utilizing fuzzy and UCE in soft computing. The enhancement of component and service reusability is observed in a heterogeneous network. This study aims to address the user's requirements through the exploration, identification, and suggestion of the best appropriate service, employing a user-centric methodology. The system provides a user-friendly interface and suggests the appropriate services to the user.

This paper presents a unique methodology that utilizes fuzzy agent middleware to improve user experiences when computer technology is completely incorporated into everyday activities. This study aims to tackle the difficulties of managing imprecise data and enhancing user-friendly interactions by integrating fuzzy logic with intelligent agents. The results emphasize the potential of fuzzy agent middleware in enhancing user interaction within the ubiquitous soft computing framework, leading to more effective and user-centered computing systems (Wu, G., 2013). This study provides useful insights into integrating soft computing and agent-based technologies to enhance ubiquitous computing paradigms.

2 Literature Survey

As computers have become more pervasive in our daily lives, they have revolutionized how we engage with technology. However, maintaining efficient and user-friendly interactions in such settings presents special difficulties. To better address these issues and improve user engagement in ubiquitous soft computing settings, this literature review investigates the function of fuzzy agent middleware. This study explores current research and applications focusing on the fusion of fuzzy logic and intelligent agent technologies to give a thorough overview of the state of the art.

Raychoudhury et al. (2013) assess and analyze ubiquitous computing middleware. Research findings and middleware solution classification are integrated during implementation. Middleware technologies' attributes and suitability for ubiquitous computing are examined in the output values (Raychoudhury, V., 2013). This approach helps academics and practitioners choose middleware for different applications. Potential drawbacks include coverage restrictions and the need for regular upgrades to keep up with technology.

In their 2019 study, Shetty and Shetty propose a method for examining cloud data center load balancing (Shetty, S.M., 2019). The process includes data center resource use data collection, load balancing algorithm development, and simulation or empirical testing of their efficacy. Load balancing algorithms are applied to cloud data centers to test their workload distribution efficiency. The output values include load balancing, performance indicators, and data center efficiency insights. Farooq et al. (2022) study ubiquitous computing issues and cloud computing's relationship. The suggested method examines the challenges and opportunities of ubiquitous computing and cloud technologies (Farooq, M.S., 2022). Implementation involves integrating research findings and creating a conceptual framework. The output values reveal insights into ubiquitous and cloud computing integration and future research and development. This approach enhances understanding of the relationship between these paradigms. Further empirical verification may be a drawback.

Using Adaptive Ubiquitous Middleware (AUM), Pradeep et al. (2021) developed a context-aware IoT ecosystem development methodology (Pradeep, P., 2021). A dynamic middleware framework tailored to IoT system contexts is developed and implemented. Implementation involves deploying middleware in IoT settings and assessing its ability to adapt to dynamic contextual changes. Middleware structure, adaptive algorithms, and performance assessments are output values. IoT ecosystems improve context awareness. This integration may be complicated by middleware integration. Vahdat-Nejad (2023) introduces CAMID, a middleware architecture for ubiquitous computing and IoT across domains. The presented method involves developing and deploying a Context-Aware Middleware for the Internet of Things (CAMID) to support various ubiquitous computing and IoT domains (Vahdat-Nejad, H., 2023). Implementation involves deploying CAMID in multiple scenarios and assessing its effectiveness in facilitating cross-domain interactions.

Nocera et al. (2019) outline a Reflective Middleware model in their theoretical framework. This model uses fuzzy rules to add context-awareness to ubiquitous computing systems (Nocera, F., 2019).

The process includes model creation and middleware integration to increase context awareness. Reflective middleware is deployed in ubiquitous computing settings and evaluated for context-awareness injection. The output values include the reflective middleware model, fuzzy rule sets, and context-awareness improvements. Ubiquitous computing improves context awareness. However, fuzzy rule sets require specialized expertise, which may be a drawback.

Takahashi et al. (2005) describe designing and implementing a context-aware ubiquitous service agent-based middleware (Takahashi, H., 2005). The method includes middleware development, agent-based functionality integration, and ubiquitous service implementation. Implementation involves evaluating the middleware's context-aware service delivery. Middleware design, agent-based features, and context-aware service evaluations are output values. Integration of context-aware intelligent beings is a benefit of this approach. However, interactions between these entities may cause complexity. Vasanthi et al. (2021) present a novel middleware component system for ubiquitous soft computing user interaction (Vasanthi, R., 2021). The proposed system uses fuzzy agent computing to improve functionality and effectiveness. The method includes middleware development, fuzzy agent computing, and ubiquitous computing implementation.

With an emphasis on the function of fuzzy agent middleware, this literature review offers a thorough overview of the changing landscape of user interaction in pervasive soft computing systems. This survey highlights the potential of fuzzy agent middleware to improve user experiences and pave the way for more intelligent and adaptable computing systems in ubiquitous computing by synthesizing previous research and emphasizing real-world implementations.

3 Fuzzy Agent Middleware to Enhance User Experiences (FAM-EUI)

Several procedures and factors must be considered while designing a ubiquitous soft computing environment employing a fuzzy agent computing system to improve user experiences. The following are the various steps involved in the process:

Establish Goals and Conditions

Outline the system's goals in great detail first. Identify the primary objective, in this case, improving user experiences. Specify the needs, such as responsiveness, context awareness, and user preference adaptation.

System Architecture Design

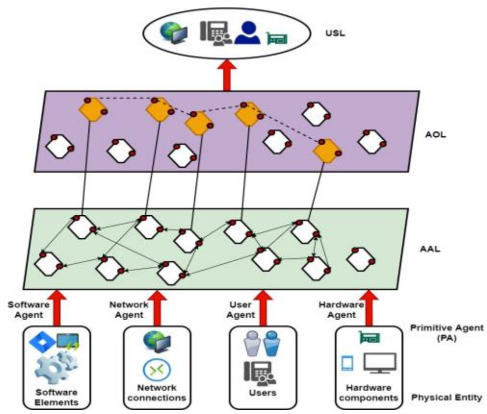

Figure 1: Agent-based Middleware Framework of UCE for Enhanced User Experience

Fig. 1 illustrates the agent-based middleware framework of UCE designed to enhance user experience. The framework is composed of four layers, namely the Primitive Agent Layer (PAL), Agent Affiliation Layer (AAL), Agent Organization Layer (AOL), and Ubiquitous Service Layer (USL), all of which are based on the concept of harmonious computing. The PAL layer transforms physical components into agents, while in the PAL layer, each entity's context is managed by its corresponding agent. The AAL layer establishes and maintains inter-agent relationships based on long-term context. The AOL layer constructs an agent organization by leveraging the context from the PAL and AAL layers when a user requests a specific service. Finally, the USL layer provides the actual ubiquitous service to users.

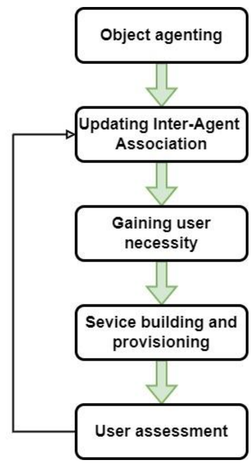

Figure 2: Service Provisioning Process for FAM-EUI Framework

The service provisioning process under the FAM-EUI framework is depicted in Fig. 2. This procedure comprises the subsequent five stages.

Object Agenting

The process involves transforming each entity into an agent by including a domain-specific knowledge representation model appropriate for classifying the entity.

Updating Inter-Agent Association (IAA)

"IAA" refers to the concept of long-term context among agents. Each agent possesses distinct IAAs concerning all other agents with whom it has engaged in cooperative activities. Each agent updates their IAA independently or via collaborative efforts with other agents.

Gaining User Necessity

The agent obtains and assesses the user's requirements based on their profile, considering their information and activity inside the ubiquitous environment. The agent must select reasonably to fulfill the criteria, as the functional input devices may not be universally accessible.

Service Building and Provisioning

Once the user demand has been obtained, agents utilize the Contract Net Protocol (CNP) to establish the structure of their organization to deliver the desired service. In this framework, we implement a hierarchical communication and coordination protocol called hierarchical CNP. This protocol involves sequential dissemination of job announcements across hardware, software, and network agents. The establishment of the agent organization is predicated on the management of context by individual agents, wherein the actual provision of services is achieved by integrating entities under the authority of these agents.

User Assessment

Upon completion of the service, the agent organization obtains feedback from the user on the quality of the service given to assess the user's satisfaction. In the FAM-EUI system, if a value undergoes a change, each agent communicates this update to all other agents with a relationship. The evaluation result is disseminated to all relevant agents, subsequently influencing the creation of services.

Agent Architecture for FAM-EUI

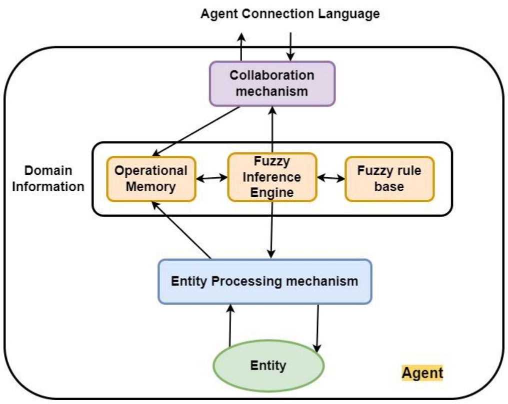

Figure 3: Fuzzy Agent Architecture in FAM-EUI

The basic architecture of the agent in FAM-EUI is shown in Fig.3. The Collaboration Mechanism (CM) refers to a mechanism that facilitates the exchange of communications between agents. Domain Information (DI) is a system that is a repository for storing and facilitating access to diverse domain knowledge related to a certain item of interest. Based on the acquired information, the agent monitors and controls the target entity and then takes action against other agents. The Entity Processing (EP) Mechanism is an intermediary between the DI system and the targeted entity. The system facilitates the transmission of events from the entity to the DI framework, including exceptions, and manages the flow of control instructions from the DI framework to the entity.

The DI framework has three distinct subsystems: operational memory, inference engine, and Fuzzy rule base. In the context of operational memory and Fuzzy rule base, it is observed that a collection of facts and rules are kept in separate entities. The term "Inference Engine" pertains to using rules and facts inside a production system. Using this inference process, the agent interacts with other agents and controls the desired entity.

The Design of the Fuzzy Agent

The Fuzzy Set Values (FSV) and their associated principles were included in the degree of involvement for each output set by selecting the maximum fuzzy value associated with each of the output sets established for each input source. This yields several attributes for each membership set that may be employed to determine the output value in the subsequent defuzzification process.

The proposed pseudocode for the design process is given in Algorithm 1.

Algorithm 1: Pseudocode for the Design Process

```
For Fuzzy Sets (FS) = Maximum FSV
        If FSV [FS+1] > -1
                If output [FSV(FS+1)] < FSV [FS]
                        Output [FSV(FS+1)] = FSV [FS]
                End If
                        Increment FS=FS+2
        End If
End
```

The process of composition is rather simple, including placing fuzzy values into an array to illustrate the resulting sets if the value is greater than the one already present. The technique as mentioned above may be implemented by utilizing Algorithm 1 and 2.

The FSV array stores the computed fuzzy values and rules during the fuzzification process. Specifically, elements [0] to [3] of the FSV array correspond to the fuzzy values and rules associated with a given input. The output array comprises the maximum values for each result set, with index [0] representing set 1, index [1] representing set 2, and so on. Subsequently, the procedure mentioned above is executed for each of the inputs, culminating in determining the maximum values for each of the resulting sets. The defuzzification process, specifically in the context of fuzzy logic systems, is a crucial step in converting fuzzy sets into crisp values.

The defuzzification procedure involves taking the array produced by the composition step and producing a single crisp value, which is then utilized to establish the rating of the action. The average of the maximum defuzzification technique is employed to compute the singular output value, determined by the maximum values of each output set and the corresponding FSV.

The pseudocode for the defuzzification process has been given in Algorithm 2.

Algorithm 2: Pseudocode for the Defuzzification Process

```
For Fuzzy Sets (FS)
        Maximum FSV = Output [FS] * Output [FS]
        Minimum FSV = Output [FS]
End For
```

The defuzzification method involves utilizing the output and the stored data about the output sets to compute the output value.

These design phases offer a foundation for developing a Ubiquitous Soft Computing Environment that improves user experiences utilizing a fuzzy agent computing system. Where appropriate, equations and mathematical models demonstrate certain design process steps. The actual application of equations and algorithms will be based on the context and particular needs of the system.

4 Results and Discussion

The study utilizes the Vicon Physical Action dataset, comprising 2,500 cases and 26 attributes. The Iris Plant dataset from the UCI repository is also used, including 140 examples and five attributes. The performance is assessed using the metrics provided below.

(a) The Number of Components (NC) represents the components needed for the process.
(b) CCT refers to the duration taken to construct the components the user requests.

(c) User load Requirement Variation (ULRV) represents the mean count of applications the user requires.
(d) The Number of Required Services (NRS) refers to the quantity of necessary services the user determines.

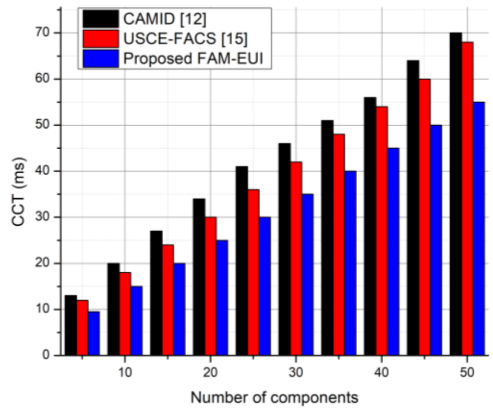

Figure 4: Performance Comparison of CCT for Varying Number of Components

Fig. 4 depicts the performance comparison of CCT for varying numbers of components. Fig. 4 compares the CCT for three distinct methods: CAMID (Vahdat-Nejad, H., 2023), USCE-FACS (Vasanthi, R., 2021), and the newly suggested FAM-EUI. The y-axis values correspond to the time, measured in milliseconds, required for constructing components in systems with varying quantities of said components. Fig. 4 provides several significant findings. Initially, it can be observed that there is a positive correlation between the number of components and the CCT for all three approaches. This phenomenon is anticipated, as bigger systems often need longer to build their individual components. Furthermore, the FAM-EUI model consistently demonstrates the lowest CCT values compared to the CAMID and USCE-FACS models. This suggests that the suggested FAM-EUI approach demonstrates higher efficiency in constructing components, resulting in notable time-saving benefits.

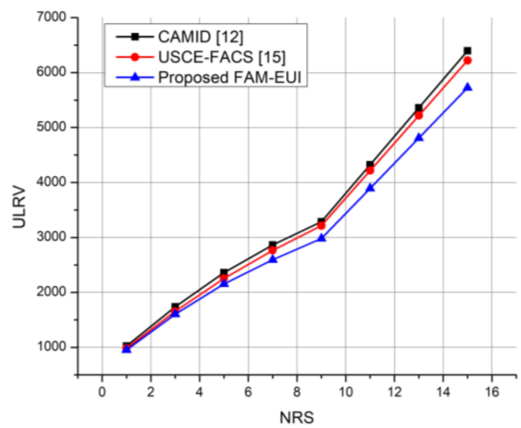

Figure 5: Performance Comparison of ULRV for Various NRS

Fig. 5 shows the performance comparison of ULRV for various NRS. Fig. 5 compares ULRV across several techniques, namely CAMID (Vahdat-Nejad, H., 2023), USCE-FACS (Vasanthi, R., 2021), and the suggested FAM-EUI. The values depicted in the graphic correspond to the ULRV metrics, which can signify the load on the system or the resource demands across varying NRS. As the NRS grows, there is a noticeable positive correlation between the number of services and the values of ULRV for all three techniques. This implies that when the demand for services expands, there is a corresponding rise in the load or resource demands. Moreover, it is apparent that the suggested FAM-EUI consistently demonstrates reduced ULRV values compared to CAMID and USCE-FACS across all NRS situations. This suggests that FAM-EUI can efficiently handle and enhance resource needs, rendering it a desirable option for fluctuating service demands.

5 Conclusion

This study introduces a novel approach, Fuzzy Agent Middleware to Enhance User Experiences (FAM-EUI), to enhance user experiences where computer technology is smoothly integrated into daily routines. This study aims to address the challenges related to inaccurate data and improve user-friendly interactions by integrating fuzzy logic with intelligent agents. The findings underscore the potential of FAM in augmenting user engagement within ubiquitous soft computing, resulting in enhanced efficiency and user-centric computing systems. This research offers valuable insights into the incorporation of soft computing and agent-based technologies to enhance ubiquitous computing paradigms. The FAM-EUI model consistently exhibits the lowest values of CCT when compared to the CAMID and USCE-FACS models. This implies that the proposed FAM-EUI methodology exhibits superior efficacy in the fabrication of components, leading to significant time-saving advantages.

Furthermore, the FAM-EUI, as recommended, consistently exhibits lower ULRV values compared to CAMID and USCE-FACS in all NRS scenarios. This implies that FAM-EUI can effectively manage and improve resource requirements, making it an attractive choice for scenarios defined by varying service demands. One of the limitations of the proposed work is the absence of an integrated architecture encompassing numerous services such as scalability, fault tolerance, flexibility, dynamicity, and reusability. Additionally, there is a lack of a uniform global framework to serve the diverse demands of consumers effectively.

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