A Study on Advanced Communication Systems for Ubiquitous Information Environments

| 収録者 | 高橋 秀幸 |
| 日 | |
| 学位授与番号 |  |
| 号 |  |

URL: http://hdl.handle.net/10097/37869
| 氏名（本籍地） | たかはし ひでき | 高橋 秀幸 |
| 学位の種類 | 博士（情報科学） |
| 学位記番号 | 情 博 第 391 号 |
| 学位授与年月日 | 平成 20 年 3 月 25 日 |
| 学位授与の要件 | 学位規則第 4 条第 1 項該当 |
| 研究科、専攻 | 東北大学大学院情報科学研究科（博士課程）情報基礎科学専攻 |
| 学位論文題目 | A Study on Advanced Communication Systems for Ubiquitous Information Environments （ユビキタス情報環境における高度な情報通信システムに関する研究） |
| 論文審査委員 | （主査）東北大学教授 白鳥 則郎 |
| | 東北大学教授 木下 哲男 東北大学教授 橋本 和夫 |
| | 東北大学准教授 菅沼 拓夫 |

論文内容の要旨

1. Introduction

In ubiquitous information society, many people, including children and elderly people, who do not have enough knowledge to use computer and network, will use the various services. Therefore, overflow of information, difficulty of use, privacy issue, information technology (IT) crime, and digital divide will become a more serious concern in the ubiquitous information society. We believe that the above problems in the ubiquitous information society originate from “gaps” between real space (RS) and the ubiquitous information environments. We therefore take an approach to overcome these problems through bridging the gaps between RS and ubiquitous information environments, with a thorough understanding of human and society by the environments.

In this research, we aim to construct technologies for information processing platform to realize advanced communication systems for ubiquitous information environments based on the situation of real space. Following three research issues are needed to be addressed to realize our purpose.

(T1) How to realize information processing platform to provide high quality service dealing with user requests and situations on ubiquitous information environments

(T2) How to achieve effective circulation of context information for ubiquitous information environments

(T3) How to accomplish provisioning of gentle multimedia communication service for users by using the proposed platform

We propose an agent-based middleware for ubiquitous services, called AMUSE, and service construction scheme with inter-agent relationship (IAR) to solve T1. To solve T2, we propose an effective context information management scheme. As for T3, we apply our proposals to a
real-time supervisory service system which behaves gently toward its users.

2. Agent-based Middleware for Ubiquitous Service Environments

In recent years, researches on ubiquitous information environments and service provisioning on the environments has been greatly accelerated. In the future, user demands on these ubiquitous services will move into much richer applications such as multimedia communication services. To provide necessary and sufficient QoS that satisfies user requirement is an intrinsic problem to realize such ubiquitous services. We propose a multiagent-based middleware for ubiquitous computing environment, called AMUSE (Agent-based Middleware for Ubiquitous Service Environment) to solve T1. Moreover, we describe design of AMUSE focusing on the service construction scheme for QoS-aware service provisioning considering the multiple contexts. Agents make organization based on CNP (Contract Net Protocol). Moreover, we model heuristics and dependency information on cooperation history in past among agents as long-term context among agents.

We performed simulation of system behavior based on AMUSE. To measure the QoS awareness, we apply User Request Achievement (URA) level. We compare three patterns of agent behaviors, i.e., IAR-based approach (our proposal), User-request approach, and Maximum approach. By analyzing Fig. 1 it can be said that when RU is always high, our approach could achieve the user requirement with higher frequency than User-request approaches. From this result, when user requirement is higher than the service environment, it can be understood that the requirement cannot be fulfilled even if only user context is considered. Moreover, when agent considers only the user request and the maximum value that can be selected, URA generally is lower than our approach, when user requirement is not fulfilled. This is because that IAR decreases the conflict of resource context. We evaluated our scheme with some simulation experiments and confirmed its remarkable usefulness in ubiquitous information environments, particularly for multimedia services.

![Graph](image_url)

**Fig. 1 Results of comparison in case that RU is always in high**
3. Context Information Management based on AMUSE

The context-aware services are the services in ubiquitous information environment based on context information (CI), which is the situation of ubiquitous entities. In ubiquitous information environment, states of entities change every second in general, and the amount of CI exchanged among entities becomes huge. It is not assumable to be able to use the computer and the network resource to circulate and manage all of them. CI with excessive QoC (Quality of Context) may be circulated and managed, according to the situation of the cooperating entities. This reduces resources that entities need for providing its main service. As a result, QoS of the entire service may be greatly decreased. Therefore, it is desirable that the mechanism can change QoC dynamically and control the amount of circulation of CI, in consideration of things such as state of entities and the form of use of CI to make the behavior of the entire system stable.

To solve T2, we aim to increase availability of services in ubiquitous information environments by managing CI effectively where computational and network resources are insufficient. Especially focusing on the up-to-dateness as QoC, this mechanism offers function that achieves appropriate QoS by dynamically adjusting and aggregating QoC according to the situation.

We did experiments to confirm that appropriate QoS can be achieved by Flexible QoC Control. We observed behavior of the system of the none Flexible QoC Control mechanism (Traditional scheme) and the proposed scheme. We measured frame rate and the time that has been spent on the switch of the output destination of service. We also measured CPU utilization rate, which is the CIs of PC entity. In the none Flexible QoC Control mechanism, the handheld PC's available CPU resource decreased. Additionally, the results show that user request (30fps) remained unsatisfied for 19 fps on the average. Moreover, the process of switching the output display devices could not be executed within reasonable time. On the other hand, in our proposed scheme, no CPU usage increased until the output device was switched, and the switching process was normally executed. The execution time for the switching was about 2 seconds. In addition, the required frame rate could be maintained, even after the service output device was switched. These are the effect of agents, as they properly control the QoC and successfully keep the QoS and stability of the whole system.

These results confirmed that our proposed scheme can provide an adequate solution for the problem. Hence, it is essential for providing suitable QoS, so that the system can control proper up-to-dateness of QoC.

4. Gentle Supervisory System for Ubiquitous Information Environments based on AMUSE

Recently, several interesting works have been done to investigate ubiquitous computing (ubicomp) environments for daily life support. In this work, we cope not only with the users' locations, but also with all the details of the situations of associated ubiquitous entities such as devices, software, networks, and users, on both sides. To resolve T3, we propose a ubiquitous supervision system (uEyes).
Real-time multimedia watching systems generally include a distributed system that delivers live video streaming captured with cameras at the watched person's site, with a PC or hand-held device at the distant supervisor site. Some research groups are working to apply this kind of system to ubicomp environments. However, when the watching person has an advanced requirement concerning the video quality, it is not guaranteed to fulfill the requirement in these existing systems. To achieve our goal, the dynamic system construction mechanism based on AMUSE is promising, considering not only a user's location, but also multiple contexts of diverse system elements such as device status, network congestion, software availability, etc. on both sides, as well as users' requirements in a systematic manner. Moreover, a robust and resilient software development infrastructure is required to handle multiple reconfiguration and extension of system components in ubicomp environments in which elements are eminently changeable.

The uEyes is implemented as a set of agents which are prepared to build applications for supervision. The instance of application is constructed in run-time according to the user requirements and situations. We implemented an application of uEyes: uEyes/ELD.

To clarify the effectiveness of our system, we compare it with a competitive scheme of existing systems, that is, location-based service configurations. The son specifies the high resolution of the video using U/I of the selection window to watch his father's facial color in this case. Here, in case of a location-based scheme, the video service was moved to the PC display of PC from the user terminal because it was judged as the nearest PC display, as shown in Fig. 2(a). However, the quality of the video was too low to see the father's facial color vividly. In contrast, our system selected the TV display and DV camera with high resolution to fulfill the user's requirement, as shown in Fig. 2(b). In terms of the software context, DVTS was selected because it can provide high-quality video. In this case, multiple contexts involving the network context, user context, software context, and display context were effectively coordinated, and the user requirement was satisfied.
In this system, multiple contexts, including the user's presence, location, detail requirements for watching, device status, available bandwidth of network, etc., in both the watched site and the watching site are considered for quality control of live video streaming.

5. Application and Evaluation of Agent-based Middleware for Ubiquitous Services

We developed two other types of applications based on AMUSE to confirm that AMUSE can apply to a broad range of ubiquitous services. The first example is a ubiquitous music distribution service as shown in Fig. 3. This service plays music from different speakers, by following the user's movement. We developed this system by reusing AMUSE agents. Therefore, we could speed up the development time. The second example is a ubiquitous jam session service as shown in Fig. 4. A user selects some paper cups with RFID tag attached. When the user closes the cups to the speakers, the speaker plays instrumental audio sources corresponding to the paper cup's instrument picture, such as dram and synthesizer, via the Internet. In fact, this service was tried by more than 90 visitors at our laboratory's open house; the system continued to provide service without experiencing any problems.

We confirmed reusability and loosely coupled characteristics of the agents through applying AMUSE to these services. AMUSE is expected to greatly contribute to the service construction and provisioning in the ubiquitous information environments.

6. Conclusion

We aimed to construct technologies of information processing platform to realize advanced communication systems for ubiquitous information environments. We confirmed the effective circulation of CI from RS to ubiquitous information environments. In ubiquitous information environments, ubiquitous service was constructed by AMUSE and service composition scheme using the CI. The user-friendly multimedia communication service was also provided from ubiquitous information environments to RS. Consequently, it is possible to provide advanced service which adapted to the situations of RS and ubiquitous information environments. Moreover this research contributes to provide services by advanced communication systems for ubiquitous information society.
論文審査結果の要旨

計算機やネットワークの情報通信資源が十分でないユビキタス情報環境において、利用者の移動に応じてマルチメディア通信サービスを提供する高度な情報通信システムを実現するためには、情報通信資源の状況の変動に柔軟に対応し利用者要求を充足するようなサービスを構成し提供する必要がある。しかしながら、ユビキタス情報環境の資源は計算機の小型化やネットワークの無線化の進展に伴って変動がより激しくなり、資源の変動に応じて安定したサービス品質(QoS)を保証することが困難となっている。著者は、資源の変動によってQoSが不安定になる問題を解消するためにミドルウェアに着目し、利用者要求や資源の状況に応じてサービスを動的に構成し提供するエージェント指向ミドルウェアに基づく効果的なサービス構成手法に関する研究に取り組んできた。本論文は、その成果をまとめたもので、全編6章からなる。

第1章は序論である。

第2章では、ユビキタス情報環境において高度な情報通信システムを実現する情報処理基盤としてエージェント指向ミドルウェアとエージェント間の関係に基づくサービス構成法を提案している。さらに、計算機シミュレーションによる評価実験を行い、本方式が利用者要求や資源の状況の変動に柔軟に対処し利用者要求を満たす安定したQoSの提供が可能であることを確認した。

第3章では、利用者や資源などの状況に関する情報であるコンテキスト情報の流通量を自律的に調整する動的なコンテキスト情報管理方式を提案している。本方式をマルチメディア通信サービスの一つであるライブストリーミングシステムに適用し評価実験を行い、従来方式と比べシステムの動作とQoSに影響を与えない効果的なコンテキスト情報の流通が可能であることを確認した。

第4章では、2章で提案したエージェント指向ミドルウェアを、高齢者見守り支援システムへ適用し評価実験を行った。その結果、利用者要求やプライバシーに配慮するなど従来にない利用者にやさしい見守りが実現可能であることが確認された。これは、ユビキタス情報環境における高度な情報システムの応用例として興味深い知見である。

第5章では、2章で提案したエージェント指向ミドルウェアをユビキタス音楽配信サービスと即興演奏支援サービスへ適用し、従来手法と比較し、そのソフトウェアモジュールの独立性や再利用性などが高いたことを確認した。これは、本提案手法の実用性と有効性に関する重要な成果である。

第6章は結論である。

以上要するに本論文は、ユビキタス情報環境における高度な情報通信システムに関し、利用者要求や多様な情報環境における資源の状況の変動に柔軟に対処し、高品質なサービスを提供する基盤技術の基礎を与えたものであり、情報基盤科学の発展に寄与するところが少なくな。

よって、本論文は、博士（情報科学）の学位論文として合格と認める。