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Multi-agent based Ambient Intelligence Platform

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Abstract

The vision of Ambient Intelligence (AmI) can be realised through the integration of embedded technologies, distributed systems, middleware and human machine interfaces and many research efforts have been made to advance these technologies. However, the exclusiveness of these ambient intelligence technologies has reduced their practical values. In this thesis, a novel AmI platform is proposed to facilitate the integration and interoperability of various technologies in the process of developing AmI applications. The platform defines the overall software/hardware architecture and communication interfaces and provides a common base for development, operation and future adaptation of AmI applications.

The proposed platform consists of four layers, the physical ubiquitous environment, middleware, multi-agent system (MAS) and application layer. The ubiquitous environment layer accommodates any type of embedded device network for interconnecting different sensors, actuators and computing devices. The middleware layer is built using an IP-based service discovery protocol, Universal Plug and Play (UPnP), which provides a unique communication interface for controlling and monitoring embedded devices. The MAS handles the core distributed and adaptive control functionality and communication with user interfaces. The application layer contains any type of user interface for different AmI applications. An XML-based content language is designed with an XML schema and seven XML messages. The content language standardises the way of interpreting contents of communication between different user interfaces and the MAS.

Based on the proposed platform, a complete AmI application prototype called Distributed Embedded Intelligence Room (DEIR) has been implemented. Four different device networks, the SmartHouse network, IP network, Bluetooth and Zigbee network, have been integrated in DEIR to interconnect various embedded sensors and devices. The MAS is implemented using Java Agent DEvelopment framework (JADE). Four application specific agents, known as the UPnP control point agent, IP interface agent, fuzzy inference agent and decision tree agent, are designed and implemented. The UPnP control point agent provides MAS the ability to monitor

and to control the underlying hardware devices through the UPnP middleware layer. The IP interface agent handles communication with user interfaces over socket connections. Fuzzy inference and decision tree agents are implemented to provide personalised learning and automated control capabilities. Three user interfaces, including a remote graphical user interface, a mobile PDA interface and a 3D virtual reality interface are implemented. Contents of communication between these user interfaces and the MAS are encoded using the proposed XML content language and transmitted over socket connections.

The AmI application prototype, DEIR, has demonstrated the ability of integrating multiple device networks and multiple user interfaces, which is a vital feature for most AmI applications. Two case studies have been carried out to incorporate two adaptive learning and controlling algorithms, known as the adaptive online fuzzy inference system (AOFIS) and ID3 decision tree algorithm, in the MAS of DEIR. The results of case studies show that DEIR has the ability of incorporating multiple adaptive control algorithms as multiple agents. In addition, comparable or better offline learning accuracy and learning speed have been achieved by DEIR compared with other advanced adaptive control algorithms.

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Acronym

ABLE	Agent Building and Learning Environment
ACHE	Adaptive Control of Home Environment
ACL	Agent Communication Language
AIRE	Agent-based Intelligent Reactive Environments
AmI	Ambient Intelligence
AMS	Agent Management System
ANFIS	Adaptive Network-based Fuzzy Inference System
AOFIS	Adaptive Online Fuzzy Inference System
API	Application Programming Interface
BDI	Belief-Desire-Intention
BSIG	Bluetooth Special Interest Group
CDC	Connected Device Configuration
CEBus	Consumer Electronic Bus
CLDC	Connected Limited Device Configuration
CORBA	Common Object Request Broker Architecture
DA	Directory Agent
DEIR	Distributed Embedded Intelligence Room
DF	Directory Facilitator
DHCP	Dynamic Host Configuration Protocol
DNS	Domain Name Server
EIB	European Installation Bus
FCM	Fuzzy C-Mean
FFD	Full-Function Device
FIPA	Foundation of Intelligent Physical Agent
FLC	Fuzzy Logic Controller
GENA	General Event Notification Protocol
GP	Genetic Programming
GUI	Graphical User Interface

HCI	Human-Computer Interaction
HMI	Human Machine Interface
HTTP	HyperText Transfer Protocol
IDE	Integrated Development Environment
iDorm	intelligent Dormitory
IETF	Internet Engineering Task Force
IP	Internet Protocol
IPMS	Inter-Platform Mobility Service
IrDA	Infrared Data Association
ISM	Industrial, Scientific and Medical
ISTAG	Information Society Technologies Advisory Group
JADE	Java Agent DEvelopment framework
JAL	JACK® Agent Language
JDE	JACK® Development Environment
JVM	Java Virtual Machine
LDR	Light Dependent Resistor
LEAP	Lightweight Extensible Agent Platform
LGPL	Lesser General Public License
MAC	Media Access Control
MAFIS	Multi-Agent Fuzzy Inference System
MAHIS	Multi-Agent Hybrid Intelligence System
MAS	Multi Agent System
mDNS	multicast Domain Name Server
MIDP	Mobile Information Device Profile
MIMO	Multiple Inputs, Multiple Outputs
MISO	Multiple Inputs, Single Output
MLP	Multi-Layer Perceptron
OSGi	Open Service Gateway initiative
OSI	Open System Interconnection
PIR	Passive Infra Red
PLC	Power Line Communication
PnP	Plug and Play
RF	Radio Frequency
RFD	Reduced Function Device
RMA	Remote Monitoring Agent
RMI	Remote Method Invocation
RMSE	Root Mean Square Error
RPC	Remote Procedure Call

SA	Service Agent
SDP	Service Discovery Protocol
SLP	Service Location Protocol
SOAP	Simple Object Access Protocol
SOHO	Small Office, Home Office
SRMSE	Scaled Root Mean Square Error
SSDP	Simple Service Discovery Protocol
TP	Twisted Pair
UA	User Agent
UPnP	Universal Plug and Play
URL	Uniform Resource Locator
USB	Universal Serial Bus
UTP	Unshielded Twisted Pair
WPAN	Wireless Personal Area Network
XML	eXtensible Markup Language

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