Distributed Support for Intelligent Environments

A thesis submitted for the degree of
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Teddy Mantoro

Department of Computer Science
The Australian National University
ACT 0200, Australia
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Declaration

I declare that the research described in this thesis is my own original work during my PhD study under the supervision of the members of advisory panel, i.e. Assoc. Prof. Christopher W. Johnson (chair and main supervisor), Assoc. Prof. Bob Kummerfeld (co-supervisor) and Dr. Ken Taylor (co-supervisor), except where otherwise acknowledged in the text.

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Publications

Journals:

1. Mantoro, T., and C. W. Johnson, **Fusing Sensors to Enabling Intelligent Responses in an Active Office**, Submitted to the Journal of Pervasive and Mobile Computing (PMC) by Elsevier, ISSN 1574-1192, December 2004.
2. Mantoro, T., and C. W. Johnson, **Instance-Based Learning Methods for the Best Estimation of Topological User Location in Pervasive Environments**, Submitted to the International Journal of Mobile Computing and Communication Review (MC^2R), ACM SIGMOBILE , May 2005.
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Glossary of Abbreviations

AmI	Ambient Intelligence
AI	Artificial Intelligent
ANN	Artificial Neural Network
ANU	The Australian National University
AP	Access Point
API	Application Program Interface
ASR	Automatic Speech Recognition
Aura	An Architectural Framework for User Mobility in Ubiquitous Computing Environments. Carnegie Mellon University: "Distraction-free Ubiquitous Computing"
BDA	Bluetooth Device Address
Bluetooth	Short distance wireless cable replacement technology
Bluejacking	The sending of unsolicited message over Bluetooth to Bluetooth-enable devices, such as mobile phones, PDAs Smart Phones or Laptops
BT	Bluetooth
CAIP	Centre for Advanced Information Processing
CIPE	Crypto Internet Protocol Encapsulation
CLIPS	C Language Integrated Production System
CMU-TMI	Carnegie Mellon University – Triangulation Mapping Interpolation
CS	Computer Science
CSIT	Computer Science and Information Technology
DB	Database
DCS	Department of Computer Science
DHCP	Dynamic Host Configuration Protocol
DHT	Distributed Hash Table
DiCPA	Distributed Context Processing Architecture
DNS	Domain Name Server
DSTO	Defence Science and Technology Organisation
ECIS	European Conference on Information Systems
ECSE	Experimental Computer Science and Engineering
Ekahau	Commercial software which has capability to locate location in wireless (IEEE 802.11) local area network environment.
ESPRIT MUSiC	European information technologies (IT) programme (ESPRIT) Measurement of Usability in Context
FEIT	Faculty of Engineering and Information Technology
GPRS	General Package Radio Service
GPS	Global Position System
GSM	Global System for Mobile Communications
HCI	Human Computer Interaction
HTTP	Hypertext Transfer Protocol
ICMP	Internet Control Message Protocol
ID	Identification
IE	Intelligent Environment

IEC	International Electrotechnical Commission
IEEE	Institute of Electrical and Electronics Engineers
IMAP	Internet Message Access Protocol
IP	Internet Protocol
IrDA	Infra-red Data Association
IROS	Interactive Room (iRoom) Operating System
ISO	International Standardization Organization
JESS	Java Expert System Shell
JINI	An open software architecture that enables Java Dynamic Networking for building distributed systems that are highly adaptive to change.
JSAPI	Java Speech Application Program Interface
JXTA	Stands for Project Juxtapose (more simply, JXTA)
k-NN	*k*-Nearest Neighbour
LCE	Laboratory for Communications Engineering, Cambridge
LDAP	Lightweight Directory Access Protocol
MAC address	Media Access Control address
MCDM	Multiple Criteria Decision Making
MCRDR	Multiple Classification Ripple Down Rules
MIT	Massachusetts Institute of Technology
MRTG	Multi Router Traffic Grapher
NAPTR	Naming Authority Pointer
NAT	Network Address Translation
Nibble	A Wi-Fi location service that uses Bayesian networks to infer the location of a device.
NIS(YP)	Network Information Service (Yellow Page)
ntop	Network TOP – A network traffic probe that shows the network usage
P2P	Peer-to-Peer
PAN	Personal Area Network
PANU	Personal Access Network User
PARC	Palo Alto Research Center (Xerox)
PCA	Principal Component Analysis
PDA	Personal Digital Assistance
POP3	The PPTP server solution for Linux
PoPToP	The PPTP server solution for Linux
PPTP	Point to Point Tunnelling Protocol
PPPd	Point-to-Point Protocol daemon
PURL	Persistent Unique Resolution Protocol
RADAR	A radio-frequency (RF) based system for locating and tracking users inside buildings.
RBAC	Role-Based Access Control
RFC	Request For Comment
ROADMAP	Role-Oriented Analysis and Design for Multi-Agent Programming; a generic meta-model for describing multi-agent systems

RPC	Remote Procedure Call
RFID	Radio Frequency Identification
RJ45	Registered Jack - Type 45
RPC	Remote Procedure Call
RR	Resources Record
SADT	Structured Analysis and Design Technique
SEA	Smart Environment Agent
SNMP	Simple Network Management Protocol
SOM	Self Organising Map
SPA	Smart Personal Assistant
SpeechCA	Speech Context-Aware
SQL	Select Query Language
UDP	User Datagram Protocol
UMTS	Universal Mobile Telecommunications System
UPnP	Universal Plug and Play
URI	Unique Resolution Identifier
URL	Unique Resolution Locator
URN	Unique Resolution Name
USB	Universal Serial Bus
UWB	Ultra-Wideband
VNC	Virtual Network Computing
VPN	Virtual Private Network
WAAS	Wide Area Augmentation System
WiFi	Wireless Fidelity, the Alliance to certify interoperability of IEEE 802.11
WiMedia	Brand for high data-rate, wireless multimedia networking applications operating in a WPAN
WLAN	Wireless Local Area Network
WPAN	Wireless Personal Area Network
WVLAN	Wireless Virtual Local Area Network
XDM	X Display Manager (a graphical windows which manage remote X servers and provide login prompts to remote 'X terminals' or to manage the users X session)
X-terminals	A machine with a network connection, keyboard, mouse and monitor, configured to run the X Windows System to connect to an application server on the network
Zigbee	A combination of HomeRF Lite and the IEEE 802.15.4 specification
ηk-NN	ηk-Nearest Neighbour

Abstract

This thesis describes research on methods for Ubiquitous/Pervasive Computing to better suit users in an Intelligent Environment. The approach is to create and equip a computing environment, such as our Active Office, with technologies that can identify user needs and meet these need in a timely, efficient and unobtrusive manner.

The critical issues in the Intelligent Environment are how to enable transparent, distributed computing to allow continued operation across changing circumstances and how to exploit the changing environment so that it is aware of the context of user location, the collection of nearby people and objects, accessible devices and changes to those objects over time.

Since the Intelligent Environment is an environment with rapid and rich computing processing, the distributed context processing architecture (DiCPA) was developed to manage and respond to rapidly changing aggregation of sensor data. This architecture is a scalable distributed context processing architecture that provides: 1. continued operation across changing circumstances for users, 2. the collection of nearby people and objects, 3. accessible devices and 4. the changes to those objects over time in the environment. The DiCPA approach focuses on how the Intelligent Environment provides context information for user location, user mobility and the user activity model. Users are assumed mobile within the Intelligent Environment and can rapidly change their access to relevant information and the availability of communications and computational resources.

Context-Aware Computing is a new approach in software engineering for Intelligent Environment. It is an approach in the design and construction of a context-aware application that exploits rapid changes in access to relevant information and the availability of communication and computing resources in the mobile computing environment. The goal of Context-Aware Computing is to make user interaction with the computer easier in the smart environment where technology is spread throughout (pervasive), computers are everywhere at the same time (ubiquitous) and technology is embedded (ambient) in the environment. Context-aware applications need not be difficult, tedious or require the acquisition of new skills on the part of the user. They should be safe, easy, simple to use and should enable new functionality without the need to learn new technology. They should provide relevant information and a simple way for a user to manage.

The Intelligent Environment requires a context-aware application to improve its efficiency and to increase productivity and enjoyment for the user. The context awareness mechanism has four fundamental cores i.e. identity (who), activity (what), location (where) and timestamp (when). Based on DiCPA architecture, the model of user location (where), user mobility (where), user activity (what) and Intelligent Environment response (what) were developed. Prototypes were also developed to proof the Context-Aware Computing concept in the Intelligent Environment.

An Intelligent Environment uses the multi-disciplinary area of Context-Aware Computing, which combines technology, computer systems, models and reasoning, social aspects, and user support. A “good quality” project for Context-Aware Computing requires *core content* and provides *iterative evaluation* processes, which has two types of iteration: design and product iteration of the evaluation. The aim of the development of an evaluation program in Context-Aware Computing is to determine what to test, how to

test and the appropriate metrics to use. This work presents the metrics for a good quality project in the Context-Aware Computing area, which is followed by the evaluation of the prototypes of this work.

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