Michael G. Hinchey Patricia Rago
James L. Rash Christopher A. Rouff
Roy Sterritt Walt Truszkowski (Eds.)

LNAI 3825

Innovative Concepts for Autonomic and Agent-Based Systems

Second International Workshop on Radical Agent Concepts, WRAC 2005
Greenbelt, MD, USA, September 2005, Revised Papers

Workshop on Radical Agent Concepts
Think Outside The Box!
WRAC

Springer

Michael G. Hinchey Patricia Rago
James L. Rash Christopher A. Rouff
Roy Sterritt Walt Truszkowski (Eds.)

Innovative Concepts for Autonomic and Agent-Based Systems

Second International Workshop
on Radical Agent Concepts, WRAC 2005
Greenbelt, MD, USA, September 20-22, 2005
Revised Papers

Springer

Series Editors

Jaime G. Carbonell, Carnegie Mellon University, Pittsburgh, PA, USA
Jörg Siekmann, University of Saarland, Saarbrücken, Germany

Volume Editors

Michael G. Hinchey
James L. Rash
Walt Truszkowski

NASA Software Engineering Laboratory, NASA Goddard Space Flight Center
Greenbelt, MD 20771, USA
E-mail: {Michael.G.Hinchey,James.L.Rash,Walter.F.Truszkowski}@nasa.gov

Patricia Rago
IBM Autonomic Computing
Raleigh, NC, USA
E-mail: ragopat@us.ibm.com

Christopher A. Rouff
SAIC
McLean, VA 22102, USA
E-mail: rouffc@saic.com

Roy Sterritt
University of Ulster
Jordanstown, Northern Ireland
E-mail: r.sterritt@ulster.ac.uk

Library of Congress Control Number: 2006938753

CR Subject Classification (1998): I.2.11, I.2, D.2, C.2.4, H.5.2-3

LNCS Sublibrary: SL 7 – Artificial Intelligence

ISSN	0302-9743
ISBN-10	3-540-69265-7 Springer Berlin Heidelberg New York
ISBN-13	978-3-540-69265-2 Springer Berlin Heidelberg New York

Springer is a part of Springer Science+Business Media

springer.com

Printed in Germany

Typesetting: Camera-ready by author, data conversion by Scientific Publishing Services, Chennai, India
Printed on acid-free paper SPIN: 11964995 06/3142 5 4 3 2 1 0

Lecture Notes in Artificial Intelligence 3825

Edited by J. G. Carbonell and J. Siekmann

Subseries of Lecture Notes in Computer Science

Preface

The second WRAC, NASA/IEEE Workshop on Radical Agent Concepts, was held at NASA Goddard Space Flight Center, Greenbelt, MD, September 20–22, 2005.

The workshop was sponsored by the Information Systems Division of NASA Goddard and IEEE Computer Society Technical Committee on Complexity in Computing and IEEE Task Force on Autonomous and Autonomic Systems. The workshop also received generous financial support from IBM, without which the workshop would not have been possible.

Agent technology, along with autonomous and autonomic computing, has emerged as a major field in computing, and will greatly influence the future development of complex computer-based systems. The area of research is strongly influenced by the autonomic computing initiative as well as by developments in biologically inspired computing, and involves interdisciplinary interaction from those involved in research in social intelligence, psychology, arts, biology, computer science, computer communications and philosophy.

This volume includes revised versions of papers presented at the workshop. The workshop was structured so as to allow adequate time for discussion and interaction, to exchange ideas and reflect on the motivations, scientific grounds and practical consequences of the concepts presented. Many of the ideas are truly "radical", and so authors were given time to revise their papers to reflect further thoughts on the ideas presented and to reflect feedback received at the workshop.

We are grateful to Jeff Kephart for a very interesting keynote speech describing IBM's current and future work in this field, which fit very well with the aims and scope of the workshop.

Again, we would like to express our thanks to NASA Goddard, IEEE Computer Society and IBM for their support of this event. Our thanks also to Alfred Hofmann and Anna Kramer of Springer for their support and interest in publishing these proceedings. We hope the papers are of interest to the reader, and we hope to welcome you soon to the next Workshop on Radical Agent Concepts.

October 2006

Mike Hinchey
Patricia Rago
Jim Rash
Chris Rouff
Roy Sterritt
Walt Truszkowski

Lecture Notes in Artificial Intelligence (LNAI)

Vol. 4342: H. de Swart, E. Orłowska, G. Schmidt, M. Roubens (Eds.), Theory and Application of Relational Structures as Knowledge Instruments II. X, 373 pages. 2006.

Vol. 4333: U. Reimer, D. Karagiannis (Eds.), Practical Aspects of Knowledge Management. XII, 338 pages. 2006.

Vol. 4327: M. Baldoni, U. Endriss (Eds.), Declarative Agent Languages and Technologies IV. VIII, 257 pages. 2006.

Vol. 4304: A. Sattar, B.-h. Kang (Eds.), AI 2006: Advances in Artificial Intelligence. XXVII, 1303 pages. 2006.

Vol. 4303: A. Hoffmann, B.-h. Kang, D. Richards, S. Tsumoto (Eds.), Advances in Knowledge Acquisition and Management. XI, 259 pages. 2006.

Vol. 4293: A. Gelbukh, C.A. Reyes-Garcia (Eds.), MICAI 2006: Advances in Artificial Intelligence. XXVIII, 1232 pages. 2006.

Vol. 4289: M. Ackermann, B. Berendt, M. Grobelnik, A. Hotho, D. Mladenič, G. Semeraro, M. Spiliopoulou, G. Stumme, V. Svatek, M. van Someren (Eds.), Semantics, Web and Mining. X, 197 pages. 2006.

Vol. 4285: Y. Matsumoto, R. Sproat, K.-F. Wong, M. Zhang (Eds.), Computer Processing of Oriental Languages. XVII, 544 pages. 2006.

Vol. 4274: Q. Huo, B. Ma, E.-S. Chng, H. Li (Eds.), Chinese Spoken Language Processing. XXIV, 805 pages. 2006.

Vol. 4265: L. Todorovski, N. Lavrač, K.P. Jantke (Eds.), Discovery Science. XIV, 384 pages. 2006.

Vol. 4264: J.L. Balcázar, P.M. Long, F. Stephan (Eds.), Algorithmic Learning Theory. XIII, 393 pages. 2006.

Vol. 4259: S. Greco, Y. Hata, S. Hirano, M. Inuiguchi, S. Miyamoto, H.S. Nguyen, R. Słowiński (Eds.), Rough Sets and Current Trends in Computing. XXII, 951 pages. 2006.

Vol. 4253: B. Gabrys, R.J. Howlett, L.C. Jain (Eds.), Knowledge-Based Intelligent Information and Engineering Systems, Part III. XXXII, 1301 pages. 2006.

Vol. 4252: B. Gabrys, R.J. Howlett, L.C. Jain (Eds.), Knowledge-Based Intelligent Information and Engineering Systems, Part II. XXXIII, 1335 pages. 2006.

Vol. 4251: B. Gabrys, R.J. Howlett, L.C. Jain (Eds.), Knowledge-Based Intelligent Information and Engineering Systems, Part I. LXVI, 1297 pages. 2006.

Vol. 4248: S. Staab, V. Svátek (Eds.), Managing Knowledge in a World of Networks. XIV, 400 pages. 2006.

Vol. 4246: M. Hermann, A. Voronkov (Eds.), Logic for Programming, Artificial Intelligence, and Reasoning. XIII, 588 pages. 2006.

Vol. 4223: L. Wang, L. Jiao, G. Shi, X. Li, J. Liu (Eds.), Fuzzy Systems and Knowledge Discovery. XXVIII, 1335 pages. 2006.

Vol. 4213: J. Fürnkranz, T. Scheffer, M. Spiliopoulou (Eds.), Knowledge Discovery in Databases: PKDD 2006. XXII, 660 pages. 2006.

Vol. 4212: J. Fürnkranz, T. Scheffer, M. Spiliopoulou (Eds.), Machine Learning: ECML 2006. XXIII, 851 pages. 2006.

Vol. 4211: P. Vogt, Y. Sugita, E. Tuci, C.L. Nehaniv (Eds.), Symbol Grounding and Beyond. VIII, 237 pages. 2006.

Vol. 4203: F. Esposito, Z.W. Raś, D. Malerba, G. Semeraro (Eds.), Foundations of Intelligent Systems. XVIII, 767 pages. 2006.

Vol. 4201: Y. Sakakibara, S. Kobayashi, K. Sato, T. Nishino, E. Tomita (Eds.), Grammatical Inference: Algorithms and Applications. XII, 359 pages. 2006.

Vol. 4200: I.F.C. Smith (Ed.), Intelligent Computing in Engineering and Architecture. XIII, 692 pages. 2006.

Vol. 4198: O. Nasraoui, O. Zaïane, M. Spiliopoulou, B. Mobasher, B. Masand, P.S. Yu (Eds.), Advances in Web Mining and Web Usage Analysis. IX, 177 pages. 2006.

Vol. 4196: K. Fischer, I.J. Timm, E. André, N. Zhong (Eds.), Multiagent System Technologies. X, 185 pages. 2006.

Vol. 4188: P. Sojka, I. Kopeček, K. Pala (Eds.), Text, Speech and Dialogue. XV, 721 pages. 2006.

Vol. 4183: J. Euzenat, J. Domingue (Eds.), Artificial Intelligence: Methodology, Systems, and Applications. XIII, 291 pages. 2006.

Vol. 4180: M. Kohlhase, OMDoc – An Open Markup Format for Mathematical Documents [version 1.2]. XIX, 428 pages. 2006.

Vol. 4177: R. Marín, E. Onaindía, A. Bugarín, J. Santos (Eds.), Current Topics in Artificial Intelligence. XV, 482 pages. 2006.

Vol. 4160: M. Fisher, W. van der Hoek, B. Konev, A. Lisitsa (Eds.), Logics in Artificial Intelligence. XII, 516 pages. 2006.

Vol. 4155: O. Stock, M. Schaerf (Eds.), Reasoning, Action and Interaction in AI Theories and Systems. XVIII, 343 pages. 2006.

Vol. 4149: M. Klusch, M. Rovatsos, T.R. Payne (Eds.), Cooperative Information Agents X. XII, 477 pages. 2006.

Vol. 4140: J.S. Sichman, H. Coelho, S.O. Rezende (Eds.), Advances in Artificial Intelligence - IBERAMIA-SBIA 2006. XXIII, 635 pages. 2006.

Vol. 4139: T. Salakoski, F. Ginter, S. Pyysalo, T. Pahikkala (Eds.), Advances in Natural Language Processing. XVI, 771 pages. 2006.

Vol. 4133: J. Gratch, M. Young, R. Aylett, D. Ballin, P. Olivier (Eds.), Intelligent Virtual Agents. XIV, 472 pages. 2006.

Vol. 4130: U. Furbach, N. Shankar (Eds.), Automated Reasoning. XV, 680 pages. 2006.

Vol. 4120: J. Calmet, T. Ida, D. Wang (Eds.), Artificial Intelligence and Symbolic Computation. XIII, 269 pages. 2006.

Vol. 4118: Z. Despotovic, S. Joseph, C. Sartori (Eds.), Agents and Peer-to-Peer Computing. XIV, 173 pages. 2006.

Vol. 4114: D.-S. Huang, K. Li, G.W. Irwin (Eds.), Computational Intelligence, Part II. XXVII, 1337 pages. 2006.

Vol. 4108: J.M. Borwein, W.M. Farmer (Eds.), Mathematical Knowledge Management. VIII, 295 pages. 2006.

Vol. 4106: T.R. Roth-Berghofer, M.H. Göker, H.A. Güvenir (Eds.), Advances in Case-Based Reasoning. XIV, 566 pages. 2006.

Vol. 4099: Q. Yang, G. Webb (Eds.), PRICAI 2006: Trends in Artificial Intelligence. XXVIII, 1263 pages. 2006.

Vol. 4095: S. Nolfi, G. Baldassarre, R. Calabretta, J.C.T. Hallam, D. Marocco, J.-A. Meyer, O. Miglino, D. Parisi (Eds.), From Animals to Animats 9. XV, 869 pages. 2006.

Vol. 4093: X. Li, O.R. Zaïane, Z. Li (Eds.), Advanced Data Mining and Applications. XXI, 1110 pages. 2006.

Vol. 4092: J. Lang, F. Lin, J. Wang (Eds.), Knowledge Science, Engineering and Management. XV, 664 pages. 2006.

Vol. 4088: Z.-Z. Shi, R. Sadananda (Eds.), Agent Computing and Multi-Agent Systems. XVII, 827 pages. 2006.

Vol. 4087: F. Schwenker, S. Marinai (Eds.), Artificial Neural Networks in Pattern Recognition. IX, 299 pages. 2006.

Vol. 4068: H. Schärfe, P. Hitzler, P. Øhrstrøm (Eds.), Conceptual Structures: Inspiration and Application. XI, 455 pages. 2006.

Vol. 4065: P. Perner (Ed.), Advances in Data Mining. XI, 592 pages. 2006.

Vol. 4062: G.-Y. Wang, J.F. Peters, A. Skowron, Y. Yao (Eds.), Rough Sets and Knowledge Technology. XX, 810 pages. 2006.

Vol. 4049: S. Parsons, N. Maudet, P. Moraitis, I. Rahwan (Eds.), Argumentation in Multi-Agent Systems. XIV, 313 pages. 2006.

Vol. 4048: L. Goble, J.-J.C.. Meyer (Eds.), Deontic Logic and Artificial Normative Systems. X, 273 pages. 2006.

Vol. 4045: D. Barker-Plummer, R. Cox, N. Swoboda (Eds.), Diagrammatic Representation and Inference. XII, 301 pages. 2006.

Vol. 4031: M. Ali, R. Dapoigny (Eds.), Advances in Applied Artificial Intelligence. XXIII, 1353 pages. 2006.

Vol. 4029: L. Rutkowski, R. Tadeusiewicz, L.A. Zadeh, J.M. Zurada (Eds.), Artificial Intelligence and Soft Computing – ICAISC 2006. XXI, 1235 pages. 2006.

Vol. 4027: H.L. Larsen, G. Pasi, D. Ortiz-Arroyo, T. Andreasen, H. Christiansen (Eds.), Flexible Query Answering Systems. XVIII, 714 pages. 2006.

Vol. 4021: E. André, L. Dybkjær, W. Minker, H. Neumann, M. Weber (Eds.), Perception and Interactive Technologies. XI, 217 pages. 2006.

Vol. 4020: A. Bredenfeld, A. Jacoff, I. Noda, Y. Takahashi (Eds.), RoboCup 2005: Robot Soccer World Cup IX. XVII, 727 pages. 2006.

Vol. 4013: L. Lamontagne, M. Marchand (Eds.), Advances in Artificial Intelligence. XIII, 564 pages. 2006.

Vol. 4012: T. Washio, A. Sakurai, K. Nakajima, H. Takeda, S. Tojo, M. Yokoo (Eds.), New Frontiers in Artificial Intelligence. XIII, 484 pages. 2006.

Vol. 4008: J.C. Augusto, C.D. Nugent (Eds.), Designing Smart Homes. XI, 183 pages. 2006.

Vol. 4005: G. Lugosi, H.U. Simon (Eds.), Learning Theory. XI, 656 pages. 2006.

Vol. 4002: A. Yli-Jyrä, L. Karttunen, J. Karhumäki (Eds.), Finite-State Methods and Natural Language Processing. XIV, 312 pages. 2006.

Vol. 3978: B. Hnich, M. Carlsson, F. Fages, F. Rossi (Eds.), Recent Advances in Constraints. VIII, 179 pages. 2006.

Vol. 3963: O. Dikenelli, M.-P. Gleizes, A. Ricci (Eds.), Engineering Societies in the Agents World VI. XII, 303 pages. 2006.

Vol. 3960: R. Vieira, P. Quaresma, M.d.G.V. Nunes, N.J. Mamede, C. Oliveira, M.C. Dias (Eds.), Computational Processing of the Portuguese Language. XII, 274 pages. 2006.

Vol. 3955: G. Antoniou, G. Potamias, C. Spyropoulos, D. Plexousakis (Eds.), Advances in Artificial Intelligence. XVII, 611 pages. 2006.

Vol. 3949: F.A. Savacı (Ed.), Artificial Intelligence and Neural Networks. IX, 227 pages. 2006.

Vol. 3946: T.R. Roth-Berghofer, S. Schulz, D.B. Leake (Eds.), Modeling and Retrieval of Context. XI, 149 pages. 2006.

Vol. 3944: J. Quiñonero-Candela, I. Dagan, B. Magnini, F. d'Alché-Buc (Eds.), Machine Learning Challenges. XIII, 462 pages. 2006.

Vol. 3937: H. La Poutré, N.M. Sadeh, S. Janson (Eds.), Agent-Mediated Electronic Commerce. X, 227 pages. 2006.

Vol. 3932: B. Mobasher, O. Nasraoui, B. Liu, B. Masand (Eds.), Advances in Web Mining and Web Usage Analysis. X, 189 pages. 2006.

Vol. 3930: D.S. Yeung, Z.-Q. Liu, X.-Z. Wang, H. Yan (Eds.), Advances in Machine Learning and Cybernetics. XXI, 1110 pages. 2006.

Vol. 3918: W.-K. Ng, M. Kitsuregawa, J. Li, K. Chang (Eds.), Advances in Knowledge Discovery and Data Mining. XXIV, 879 pages. 2006.

Table of Contents

Agent-Mediated Pro-active Web-Sites

Karin Breitman[1] and Walt Truszkowski[2]

[1] Pontificia Universidade do Rio de Janeiro
karin@inf.puc-rio.br
[2] NASA Goddard Space Flight Center
Walt.Truszkowski@nasa.gov

Abstract. In this paper we explore the concept of a Semantic Desktop in which software applications will be responsible for the automation of otherwise tedious tasks and the update of user information. We propose an ontology driven software agent solution where two major issues stand out: architecture and process. The architecture issue addresses the current static nature of information on a web page. In order to achieve the level of pro-activity desired we have to be able to identify, classify and code important bits of semantic information in a way that can be automatically manipulated by machines. The second issue relates to the strategy/strategies used to dynamically update information. Because of the variety of actions needed to update web sites e.g., monitoring changes to personal information (phone numbers, addresses, hobbies, etc.), maintaining a knowledge of institutional information, reacting to external events, reaction to political and environmental changes, etc., we hypothesize that no single strategy for maintaining dynamic information-awareness will do but that a variety of strategies need to be put into practice. We propose the creation of a community of software agents, each responsible for achieving a different set of tasks. The Semantic Desktop is achieved through the composition of the site semantics with the functionality provided by the instantiated software agents.

1 Introduction

A few years ago, we were all impressed by the statistics that over a million VCRs were constantly blinking "00:00" because their users were either ignorant about how to correct the situation or did not care to update the time. The same situation seems to be happening to personal web sites. Owners, too busy to update information, sometimes leave their pages unattended for years. Nothing is more frustrating than finding an interesting web-site that is not current A major contributing reason for out-of-date web-sites is rooted in the very nature of the web itself. Information changes so rapidly that most users feel that by the time they make needed adjustments to their web-site, it is already becoming obsolete. In this paper we argue that it is possible to semi automate the information-update process with the use of emergent software-agent technology [Williams04, Pazzani02, Woolridge99, Sycara98].

The basic idea, explored and expounded upon in this paper, is to make web-sites more pro-active in providing user centered services and updating their posted

M.G. Hinchey et al. (Eds.): WRAC 2005, LNAI 3825, pp. 1 – 12, 2006.

information. In order to do this, there needs to be access to web-based information in a format that allows for automatic manipulation of the data. The exponential growth of the Internet has dramatically increased the number of available electronic resources, e.g. articles, books, web pages and data repositories, making it more difficult to find, manipulate and present information without the aid of automation [Fensel02].

Researchers worldwide are investigating the possibility of creating a Semantic Web, an improvement to today's web, in which resources will be given meaning through machine processable/parseable languages [Berners-Lee01]. As a result, a gamut of new technologies has emerged. Among others there is the use of metadata, ontologies, semantic web services, semantic navigation, and software agents. We will explore these technologies as they pertain to the novel approach to the development of self adapting web sites that we are proposing.

2 Metadata

Most of the information available in the web today is formatted for user consumption, i.e, machines play a very small role in the interpretation and processing of information. Most data is captured using markup languages that rely on the use of tags or labels that have meaning to human beings alone. Other than processing some interfaces cues, such as font, color and heading placements, computers are able to process a very small share of the available information in the nearing 8 billion web pages.

In order to allow computers to take up a larger share of the processing, we have to provide information in a format that allows for automatic manipulation. Researchers worldwide are investigating the possibility of creating a Semantic Web, an improvement to today's web in which resources will be given meaning through machine processable languages [Berners-Lee01, Antoniou04, Gómez-Pérez04]. As a result a gamut of new technologies have emerged. Among others there is the use of metadata, ontologies, semantic web services, semantic navigation, and software agents. We will explore some of these technologies as to provide a novel approach to the development of the proposed Scientific Desktop.

In our understanding, the information relevant to the Scientific Desktop is a composition of hybrid elements, text, image, sound or video content. The set of elements are typically interrelated and organized in some coherent, however domain dependent fashion, e.g., in a personal web page we expect to find the information of an individual in the top of a page whereas at product page we would expect its specifications to come before the manufacturer's contact data.

A first step in the preparation of the information for automated processing is identifying a Taxonomy of information types, e.g. research area, technology used, contact information, institutional policies. That is not a trivial task, for the relevant information is presented in varying degrees of abstraction, for example:

- **High level (general)** – what the person is: researcher, vendor, businessman…
- **Medium level** – if researcher, what area: types of events, technology (if any), association to laboratories, entities (NFS, for instance), institutions, standards and rules that it must abide to....

- **Low level (specific)** – specific interests, colleagues it works with, institutions is connected to, special interest groups and associations he or she belongs to…

Once we identify the information type, it is possible to associate an adequate Metadata, data about data, representation for the information in question [Gilliland-Sweland97]. In the Research & Academic context most types of information are already organized by some existing taxonomy, such as the list of the Computer Science sub areas by IEEE or the NAICS. Those have to be "re-written" in some metadata compatible language, RDF for instance. Other examples are:

- People – Friend of a Friend,
- Publications – Dublin Core,
- Projects – RDF Taxonomy structured as the NFS list of research areas,
- Areas – RDF Taxonomy structured as the Societies lists of topics (for CS we could use IEEE's Computing Society),
- Physical Location and Contact information – RDF version of the University Directory, Floor Plan, vCard taxonomy,
- Academic Undergrad/Graduate Courses – RDF version of the University Catalogue.

We exemplify those information chunks using the example of the home page of a researcher, depicted in Figure 1. Bellow we list a series of information chunks that represent the information that is available on the page.

Information available:
Bio, Bibliographical Production (Conference Proceedings, Tech Reports, Books, chapters), People (Colleagues, Students, Fellow Research Project Members), Research areas(Requirements Engineering, Semantic Web, Formal Systems) Events and Conferences she is organizing, Consulting, Activity in Scientific Societies.

Fig. 1. Researcher's Home Page

For each item present in the page some annotation describing its provenance, ownership and categorization is required. To exemplify we introduce one of the many links to bibliographical references, in this case an article in a Conference:

[Breitman04] - Breitman, K.K.; Leite, J.C.S.P - Lexicon Based Ontology Construction - Lecture Notes in Computer Science 2940- Editors: Carlos Lucena, Alessandro Garcia, Alexander Romanovsky, et al. - ISBN: 3-540-21182-9 - Springer-Verlag, February 2004, pp.19-34.

Possibly the best way to describe this item would be using the Dublin Core Metadata Schema [Gill97, DC05], as illustrated in Figure 2.

Dublin Core

1. Subject: Software Engineering ***(list of subjects in IEEE)***
2. Title: Lexicon Based Ontology Construction
3. Creator : Karin Breitman
4. Description: article
5. Publisher: Springer Verlag
6. Contributor) : Julio Cesar Sampaio do Prado Leite
7. Date: February 2004
8. Type: Scientific Article
9. Format: text
10. Identifier : ISBN: 3-540-21182-9
11. Relation: ***ESSMA Project*, *C&L Tool***
12. Source:
13. Language: English
14. Coverage:
15. Rights: Springer Verlag

Fig. 2. Dublin Core Metadata Annotation for a bibliographical reference

In this case there is a hierarchy of other information nested within this reference. The co-author of the article, a colleague named Julio Cesar Sampaio do Prado Leite is an piece of information its own right and needs to be unambiguously reference. A possible metadata representation for it would use the FOAF (friend of a friend RDF markup), as follows:

```
<rdf:RDF
      xmlns:rdf="http://www.w3.org/1999/02/22-rdf-syntax-ns#"
         xmlns:foaf="http://xmlns.com/foaf/0.1/">
<foaf:Person>
      <foaf:name >Julio Cesar Sampaio do Prado Leite</foaf:name>
      <foaf:mbox rdf:resource="mailto: julio@inf.puc-rio.br " />
      <foaf:nick >Julio</foaf:nick>
      <foaf:workplacehomepage rdf:resource="http:/www.inf.puc-rio.br/~julio" />
</foaf:Person>
   </rdf:RDF>
```

Fig. 3. Friend of a Friend(FOAF) RDF representation of a colleague (co-author)

The metadata markup will be very useful in referencing and storing pieces of information. However its semantics is still very weak. In addition to the information provided about the information objects themselves, we also want to represent properties, rules and relationships that are hold among information chunks. For that purpose we propose to adopt the use and integration of ontologies. Ontologies provide a shared understanding of a given domain by providing formal definition to its main concepts, properties and relationships that hold among those. The ontology construction process is inherently compositional, in that a new domain ontology is usually build by reusing parts of existing ontologies. In the case of the proposed Scientific Desktop, there are available ontologies that can be reused in the process [Gómez-Pérez98, Guarino02].

3 Ontology

The metadata markup used to index the researcher's example in the last section is very useful in referencing and storing pieces of information, but its semantics is still very weak for our intended purposes. In addition to the information provided about the object itself, metadata, we also want to represent properties, truths (axioms) and relationships that are hold among information chunks. For that purpose we adopt the ontological representation. An ontology, as defined by Alexander Maedche [Maedche02] is described by a 5-tuple containing its core elements, i.e., concepts, relations, hierarchy, a function that relates concepts non-taxonomically and a set of axioms. The elements are defined as follows:

$O := \{\mathcal{C}, \mathcal{R}, \mathcal{HC}, rel, \mathcal{A}_O\}$ consisting of :

- Two disjoint sets, $\mathcal{C}$ (concepts) and $\mathcal{R}$ (relations),
- A concept hierarchy, $\mathcal{H}_C$: $\mathcal{H}_C$ is a directed relation $\mathcal{H}_C \subseteq C \times C$ which is called concept hierarchy or taxonomy. $\mathcal{H}_C(C1,C2)$ means $C1$ is a subconcept of $C2$,
- A function $rel: \mathcal{R} \rightarrow C \times C$ that relates the concepts non taxonomically,
- A set of ontology axioms A_O, expressed in appropriate logical language.

Figure 4 illustrates a simple example of this ontological structure. We borrow from the Researcher's Home Page for this example. We depict three concepts, Project(x), Long_term_project(y) and Researcher(z), one relation, participates_in(w) that holds between concept Long_tem_project and Researcher. The concept

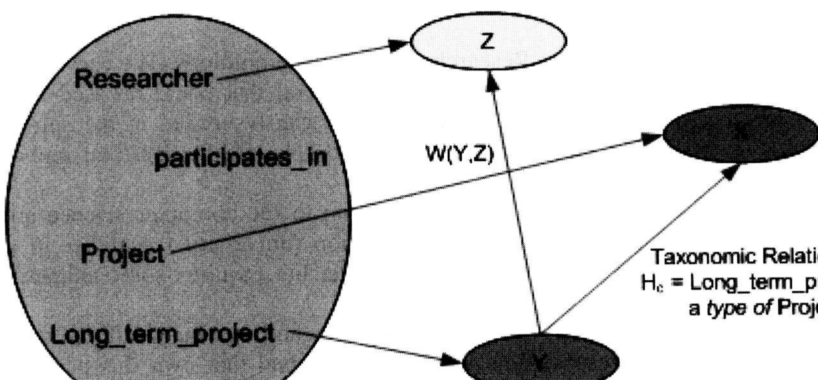

Fig. 4. Example of ontological elements and their relations using the ontology structure O proposed by [Maedche02]

Long_term_project is a subconcept of Project. According to the structure we have something like, C : = {x, y, z} and R : = {w}. The following hierarchical relation, H_C (y,x) and the non taxonomic relation, w(y,z).

Ontologies provide a shared understanding of a given domain by providing formal definition to its main concepts, properties and relationships that hold among those [Gruber93, Gómez-Pérez04, Fensel03, Breitman05]. The ontology construction process is inherently compositional, in that a new domain ontology is usually build by reusing parts of existing ontologies. In the case of the Researcher Home Page example, we can easily identify different sources that could serve in composing the information chunks concept sub trees. In table 1we exemplify some possibilities.

Table 1. Reusable Information sources for ontological composition

Information Chunk Type	Reusable Information Sources
People	FOAF Taxonomy of family and work relationships,
Research Area	IEEE taxonomy, NAICS
Events	University ontology, IEEE/ACM calendar of events
Projects	Subcategories of NSF and/or Esprit European projects
Physical Location and Contact information	University Directory, Floor Plan, vCard taxonomy
Courses	University Catalogue

In practice most of the top nodes of the ontology, i.e., the ones that represent more general concepts, can be reused from existing ontologies. As we navigate down, specializing the concepts, we identify the need of incorporating information specific to that particular ontology. Most of the construction effort will be spent in the identification and incorporation of specialized (leaf) concepts and their instances to the ontology.

In figure 5 we show part of the Researcher Home Page ontology. We can identify three zones. The top most levels are concepts so general that could be used in the creation of any personal home page. These concepts can be reused in the spirit of upper ontologies, such as Cyc [OpenCyc] and WordNet [Miller95], that embody consensual knowledge.

The second zone corresponds to the specialization to the computer science area. We would like to call this group level specialization (university researcher in the computer science area). At this level reuse is viable, but requires some adaptation level.

At the third and bottommost level, the concepts and instances added to the ontology reflect particular information about the individual that own this particular page. At this level very little reuse can be accomplished. Once ready, this ontology will model the preferences of a single, or at most a reduced number of users. Based on previous collaboration in the area of Human Computer Interaction, we are currently investigating the possibilities of using ontologies as user models [Barbosa04, Pazzani97, Perkowitz04].

This feasibility of this approach is very important to this research, because it will shape the architecture of the software agents we want to implement. If we are able to concentrate the user profile in his or her ontology, the construction and operation of the software agents will be more general and thus increase the level of agent reuse [Holvoet03].

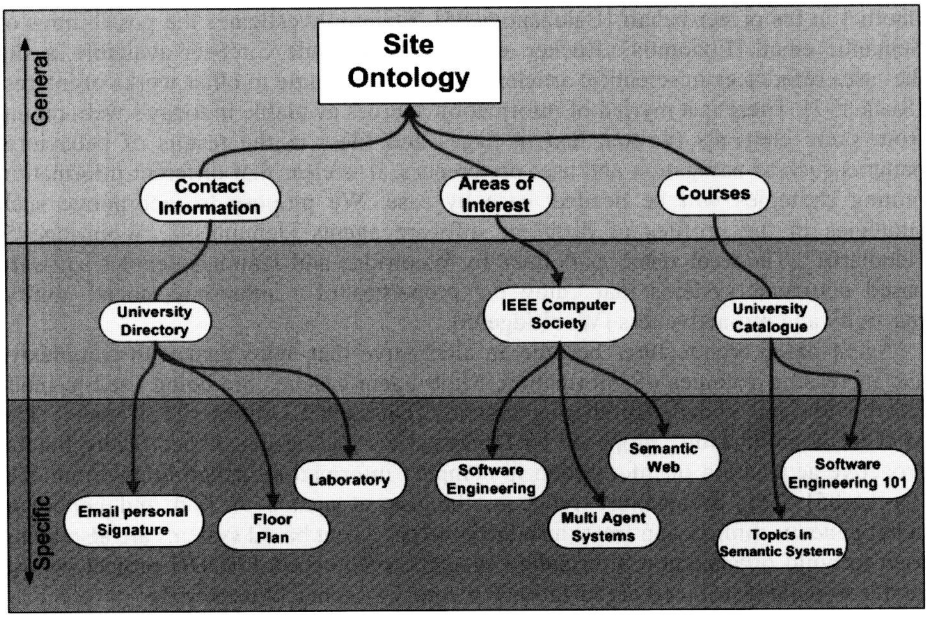

Fig. 5. Researcher Ontology (partial)

In the next section we discuss the requirements and propose an architecture, based in the concept of ontology driven software agents, to implement the proposed adapting web sites.

4 Adaptive Web-Sites

In the previous section we discuss the organization that has to imposed to the information resources in order to allow for automated computer processing. The nature of the information suggests that there are two possible types of sources:

- Internal (privately owned) – information that comes from the owner's own computer (e-mail, recent files, articles recently written/submitted, discussion groups, directory structure itself...)