SEMANTIC COMPUTING

Edited by
PHILLIP C.-Y. SHEU
HEATHER YU
C.V. RAMAMOORTHY
ARVIND K. JOSHI
LOTFI A. ZADEH

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Table of Contents

Part 2: SEMANTIC LANGUAGES AND INTEGRATION

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PREFACE

Semantic computing is emerging quickly as an interdisciplinary area that is full of promises. Tremendous amount of research has been done in the past and there is a lot more to be done in the future.

For the past three years, we have tried to give semantic computing a more precise definition; the following is a summary of our attempts, published at various times by the Institute for Semantic Computing (homepage, http://www.isc-home.org).

2007: "Semantic Computing addresses the computing technologies (e.g., artificial intelligence, natural language, software engineering, data and knowledge engineering, computer systems, signal processing, etc.), and their interactions, that may be used to extract or process the Content and Semantics of multimedia, texts, services as well as structured data."

2008: "The field of Semantic Computing (SC) brings together those disciplines concerned with connecting the (often vaguely formulated) intentions of humans with computational content. This connection can go both ways: retrieving, using and manipulating existing content according to user's goals ('do what the user means'); and creating, rearranging, and managing content that matches the author's intentions ('do what the author means')."

2008: "Computing facilitated by using the descriptions of content."

2009: "Semantic Computing is defined as a field that addresses the derivation and matching of the semantics of computational content and that of naturally expressed user intentions to help retrieve, manage, manipulate or even create the content, where 'content' may be anything including video, audio, text, process, service, hardware, network, community, etc. It brings together those disciplines concerned with connecting the (often vaguely formulated) intentions of humans with computational content. This connection can go both ways: retrieving, using and manipulating existing content according to user's goals ('do what the user means'); and creating, rearranging, and managing content that matches the author's intentions ('do what the author means')."

Until now, its "definition" is still evolving; perhaps it will not have a precise definition for good. What we know for sure is that "semantics" may play a major role in future computing.

The intention of this book is not trying to define what exactly "semantic computing" is. Rather, it is a humble effort to bring together researchers from several areas, including natural language processing, software engineering, multimedia, semantic Web, and semantic services and share with the reader what we think may contribute to a better definition of semantic computing.

Many subjects are missing in the book. One obvious reason is that we are limited by our knowledge about the broad coverage of semantic computing. Another reason may be that some subjects are already well known in the literature (e.g., data mining, keyword-based search engines). Yet another reason may be that such knowledge does not exist yet (e.g., semantic computer architecture?)

The book is divided into four parts, based on a preliminary architecture of a semantic computing system: *semantic analysis, semantic integration, semantic application*, and *semantic programming and interface*.

The book may be considered an attempt to bring together researchers with different backgrounds based on an assumption that we may have worked "together" on a common problem: finding and utilizing the "semantics" to better access or manage "content" of some sort. Hopefully a synergy may be created so we can all work even more closely to solve or address some grand challenges of computing we are facing today.

We would like to thank Ms. Mary Mann and Lisa Van Horn of Wiley for their outstanding editorial support. We thank all authors for contributing their original work to the book and sharing their wisdom with us.

PHILLIP C.-Y. SHEU

HEATHER YU

C. V. RAMAMOORTHY

ARAVIND KOSHI

LOTFI. A. ZADEH

CONTRIBUTORS

Paige Adams, Naval Post Graduate School, Monterey, California

Agnese Augello, Institute of High Performance Computing and Networking, Palermo, Italy

Fadi Almasalha, College of Engineering, Purdue University, West Lafayette, Indiana

Tansu Alpcan, Carnegie Mellon University, Pittsburgh, Pennsylvania

Uwe Assmann, University of Koblenz-Landau, Koblenz, Germany

Faisal Bashir, College of Engineering, Purdue University, West Lafayette, Indiana

Farokh B. Bastani, Department of Computer Science, University of Texas, Dallas, Texas

Christian Bauckhage, Carnegie Mellon University, Pittsburgh, Pennsylvania

Susan Windisch Brown, University of Colorado, Boulder, Colorado

Aljoscha Burchardt, Saarland University, Saarbrücken, Germany

Shih-Fu Chang, Electrical Engineering, Columbia University, New York, New York

Min Chen, Florida International University, Miami, Florida

Shu-Ching Chen, Florida International University, Miami, Florida

Christine Clark, Lymba Corporation, Richardson, Texas

Claudia D'Amato, Universita degli Studi di Bari, Bari, Italy

Colin DeLong, Naval Postgraduate School, Monterey, California

Li Deng, Microsoft Research Corporation, Redmond, Washington

Prasanna Desikan, Naval Postgraduate School, Monterey, California

Jürgen Ebert, University of Koblenz-Landau, Koblenz, Germany

Floriana Esposito, Universita degli Studi di Bari, Bari, Italy

Nicola Fanizzi, Universita degli Studi di Bari, Bari, Italy

Gerald Friedland, ICSI, University of California, Berkeley, California

Jicheng Fu, Department of Computer Science, University of Texas, Dallas, Texas

Salvatore Gaglio, Institute of High Performance Computing and Networking, Palermo, Italy

Arif Ghafoor, College of Engineering, Purdue University, West Lafayette, Indiana

Dave Gibbon, AT&T Research, Middletown, New Jersey

Haitao Gong, University of California, Irvine, California

Rodrigo Capobianco Guido, Institute of Physics at Sao Carlos, University of Sao Paulo, Sao Paulo, Brazil

Iryna Gurevych, Saarland University, Saarbrücken, Germany

Hammad Haseeb, College of Engineering, Purdue University, West Lafayette, Indiana

Jeff Heflin, Lehigh University, Bethlehem, Pennsylvania

Jakob Henriksson, University of Koblenz-Landau, Koblenz, Germany

Eero Hyvönen, Helsinki University of Technology, Helsinki, Finland

Chihiro Ishii, NEC Soft, Koto, Japan

Kenichi Kaneko, NEC Soft, Koto, Japan

Lyndon Kennedy, Columbia University, New York, New York

Ashfaq Khokhar, College of Engineering, Purdue University, West Lafayette, Indiana

Atsushi Kitazawa, NEC Soft, Koto, Japan

Harald Kühn, University of Koblenz-Landau, Koblenz, Germany

Zhu Liu, AT&T Research, Middletown, New Jersey

Craig Martel, Naval Postgraduate School, Monterey, California

Florian Metze, Carnegie Mellon University, Pittsburgh, Pennsylvania

Krzysztof Miksa, University of Koblenz-Landau, Koblenz, Germany

Dan Moldovan, Lymba Corporation, Richardson, Texas

Max Mühlhäuser, Saarland University, Saarbrücken, Germany

Martha Palmer, University of Colorado, Boulder, Colorado

Jeff Z. Pan, University of Koblenz-Landau, Koblenz, Germany

Zhengxiang Pan, Lehigh University, Bethlehem, Pennsylvania

Fernando Silva Parreiras, University of Koblenz-Landau, Koblenz, Germany

Giovanni Pilato, Institute of High Performance Computing and Networking, Palermo, Italy

Behzad Shahraray, AT&T Research, Middletown, New Jersey

Min Shen, Florida International University, Miami, Florida

Phillip C.-Y. Sheu, University of California, Irvine, California

Mei-Ling Shyu, Florida International University, Miami, Florida

Jaideep Srivastava, Computer Science and Engineering, University of Minnesota, Minneapolis, Minnesota

Steffen Staab, University of Koblenz-Landau, Koblenz, Germany

Marta Tatu, Lymba Corporation, Richardson, Texas

Stefano Tinella, University of Koblenz-Landau, Koblenz, Germany

David van Leeuwen, ICSI, University of California, Berkeley, California

Giorgio Vassallo, Institute of High Performance Computing and Networking, Palermo, Italy

Kuansan Wang, Microsoft Research Corporation, Redmond, Washington

Qi Wang, University of California, Irvine, California

Shu Wang, University of California, Irvine, California

Fei Xei, University of California, Irvine, California

I.-Ling Yen, Department of Computer Science, University of Texas, Dallas, Texas

Eric Zavesky, AT&T Research, Middletown, New Jersey

Srdjan Zivkovic, University of Koblenz-Landau, Koblenz, Germany

Chapter 1

Semantic Computing

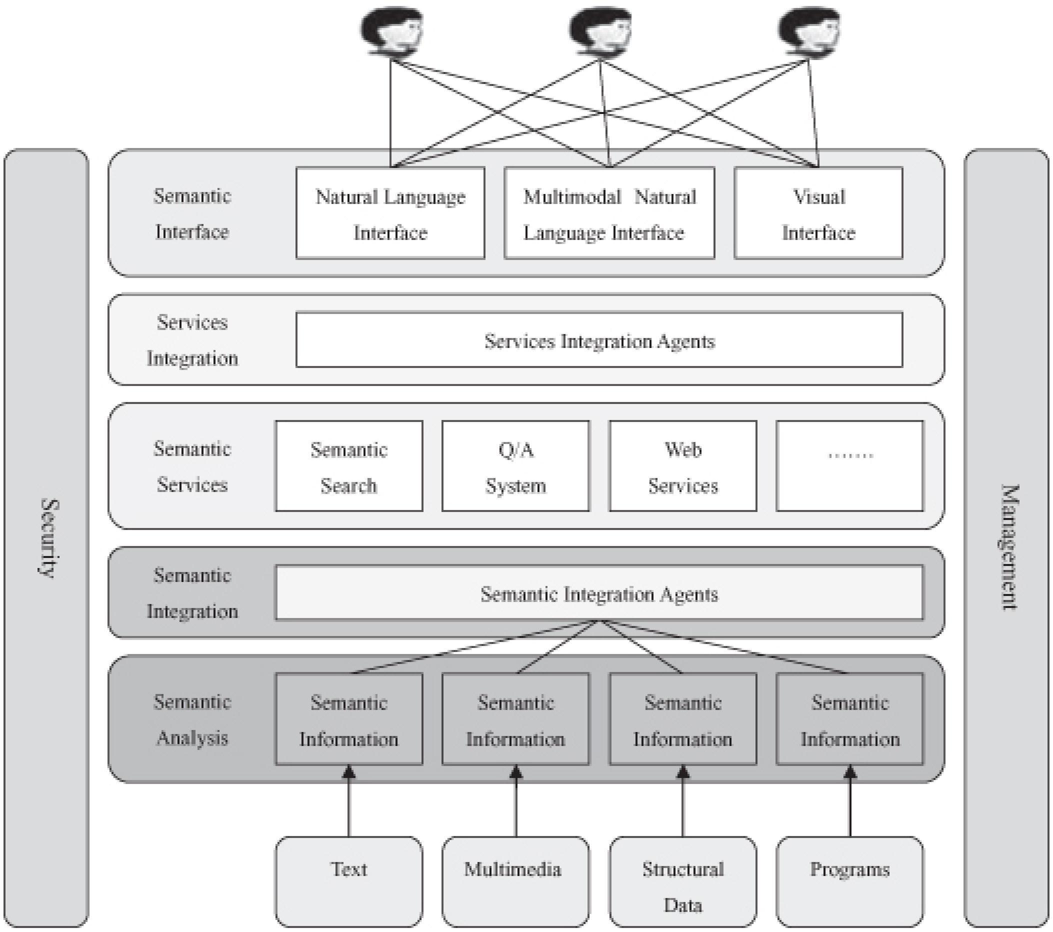
PHILLIP C.-Y. SHEU

We define semantic computing as a field that addresses the derivation and matching of the semantics of computational content and that of naturally expressed user intentions to help retrieve, manage, manipulate, or even create the content, where “content” may be anything including video, audio, text, process, service, hardware, network, community, and so on. It brings together those disciplines concerned with connecting the (often vaguely formulated) intentions of humans with computational content. This connection can go both ways: retrieving, using, and manipulating existing content according to user’s goals (“do what the user means”) and creating, rearranging, and managing content that matches the author’s intentions (“do what the author means”).

1.1 CONNECTIONS BETWEEN CONTENT AND INTENTIONS

The connection between content and the user can be made via (1) semantic analysis, which analyzes content with the goal of converting it to a description (semantics); (2) semantic integration, which integrates content and semantics from multiple sources; (3) semantic services, which utilize content and semantics to solve problems; and (4) service integration, which integrates different kinds of service to provide more powerful services; and (5) semantic interface, which attempts to interpret naturally expressed user intentions (Fig. 1.1). The reverse connection converts descriptions of user intentions to create content of various sorts via techniques of analysis and synthesis.

Figure 1.1 Architecture of semantic computing.



Note that as most of the information is sent and received through a network, security is needed at multiple levels including data-level [1], communication level [1], database level [2], application level [3] and system (community) level [4]. The flows of information are controlled both horizontally and vertically to assure desirable properties including QoS (quality of services) [5, 6] and integrity.

1. *Semantic Analysis*—analyzes and converts signals such as pixels and words (content) to meanings (semantics).

2. *Semantic Integration*—integrates the content and semantics from different sources with a unified model; it also includes languages and methodologies needed for developing semantic applications.

3. *Semantic Services*—utilize the content and semantics to solve problems, and some applications may be made available to other applications as services.

4. *Service Integration*—integrates different services to provide more powerful service.

5. *Semantic Interface*—allows the user intentions to be described in a natural form.

1.2 SEMANTIC ANALYSIS

“Semantic analysis is the process of relating syntactic structures, from the levels of phrases, clauses, sentences and paragraphs to the level of the text as a whole, to their language-independent meanings, removing features specific to particular linguistic and cultural contexts, to the extent that such a project is possible. The elements of idiom and figurative speech, being cultural, must also be converted into relatively invariant meanings.”[1] Semantic analysis is the foundation of semantic computing; it provides the information resource for semantic integration and semantic services.

The research areas related to semantic analysis include but are not limited to:

1. Natural language understanding and processing
2. Understanding and processing of texts and multimodal content
3. Understanding of texts, images, videos, and audios
4. Speech recognition
5. Web mining
6. Data mining

7. Process mining

Semantic analysis may be the most developed part among the five layers of semantic computing, but it still has a lot of limitations. Most research on semantic analysis has focused on multimedia data analysis [7–9], text analysis (including shallow semantic parsing [10], latent semantic analysis [11, 12], as well as probability latent semantic analysis [13]), structural data analysis [14], and web analysis [15]. Early attempts at semantic analysis addressed complex problems such as semantic understanding, knowledge representation, and reasoning, and some progress has been reported on the understanding of certain domain-specific stories [16, 17]. The success, however, largely depends on domain-specific knowledge. A more robust approach is yet to be developed.

The output of semantic analysis is a description of content. To be useful, the description has to be machine processable. Several languages have been proposed to support such descriptions, including keywords, ontology, Moving Pictures Experts Group (MPEG), and others. In the case that automatic semantic analysis is difficult, descriptions may be generated manually in the form of annotations.

1.3 SEMANTIC INTEGRATION

Semantic integration considers the descriptions derived from the semantic analysis layer that is presented in different formats and integrates such information before it can be used. Existing work on semantic integration includes:

- *Database Schema Integration [18, 19]* Database schemas may have different structures. Schema integration aims at unifying the matching elements. Various data sources are integrated into a data warehouse.
- *Data Exchange [20, 21]* To enable data exchange, applications need to convert messages between the

formats required by different trading partners.

- *Ontology Integration (or Merging) [22–24]* Given two distinct and independently developed ontologies, it produces a fragment that captures the intersection of the original ontologies. This area is similar to that of schema integration but is more difficult in nature due to the rich and complex knowledge representation structures found in ontologies.
- *Ontology Mapping [25, 26]* Ontology mapping could provide a common layer from which several ontologies could be accessed by multiple applications. Ontology mapping is different from integration and merging because it does not try to combine several ontologies into a single, complete one.
- *Semantic Conflict Resolution [30]* This is needed to ensure semantic interoperability among heterogeneous information sources.

1.4 SEMANTIC SERVICES

A major goal of semantic computing is providing more powerful computing services for all kinds of users. Semantic services have been developed in several forms:

- *Web search*, including automatic question answering (Q/A) [32, 33] and information retrieval (e.g., Google[2] and Windows Live[3]). Both have attracted significant amount of attention in the past and at present.
- *Multimedia databases*, with a primary focus on content-based retrieval [34].
- *Domain-specific applications*, designed to support interoperable machine-to-machine interactions over a network for specific applications.[4]

1.5 SERVICES INTEGRATION

Although semantic services are useful for different kinds of users, sometime they are limited or insufficient for applications requiring several services working together.

A prerequisite for a set of services to collaborate is their ability to understand the mental model, often described in the form of ontology, of each other and communicate with each other. Mapping between ontologies is a major area of interest where automated and scalable solutions are also sought due to the vast number of services. Service integration [27–29, 31] provides the interoperation methods between different services involved in practical scenarios.

On the other hand, for service integration, a significant gap still exists between specialists and nonspecialists, or among specialists focusing on different aspects of a problem. Traditional web services provide a protocol UDDI to perform resources description, discovery and integration. However, this protocol can only be used by experienced specialists. Automatic composition of services hence is strongly desired.

1.6 SEMANTIC INTERFACE

To achieve the goal of providing more powerful computing services to all kinds of users, a portable and friendly user interface is required. This is especially important when cell phones become more capable. Standard graphical user interface (GUI) techniques such as browsing, menu trees, and online help may be far less appealing for the next-generation applications. Therefore new standards of interface, such as natural language interface, multimodal interface, and visual interface, are becoming increasingly important.

A *natural language interface* allows people to interact using a form of a human language, such as English, as opposed to a computer language, a command line interface, or a GUI. Natural language interfaces may be designed for understanding either written or spoken texts. Attempts have been made to replace command lines and database queries with some form of natural language queries and to use some natural language syntax for programming languages. The most common problem of a true natural language interface is ambiguity: The same sentence may have multiple interpretations. Another problem is that users often assume that computers can reason as a human being and has the full knowledge as a human being.[5]

A *multimodal natural language interface* combines natural language input with other forms of input such as gesture. There are several strong reasons for creating an interface that allows voice to be combined with gesture as the input [35]:

- Expression is easy.
- Voice and gesture complement each other and when used together create an interface more powerful than either modality alone.
- Combining speech and gesture may improve the accuracy of recognition and reduce the length of speech, resulting in faster task completion compared to using speech alone.
- Users work more efficiently by using speech and gesture together.

In addition to understanding user intentions, a semantic interface should be able to present the result produced by a semantic application in a form that can be easily understood by the user. In online analytical processing (OLAP), for example, it is important to provide a reporting tool on top of the server. Research on visualization allows the user to effectively visualize complex systems of information/data; it