Resumen

Actualmente, existe una expansión de gran cantidad de sistemas de información disponibles tanto en la Web como dentro de una misma organización. A su vez, muchos de estos sistemas involucran información geográfica para representar simples instancias del mundo real. Es imposible hoy en día pensar en representar información de un lugar, como una casa particular o un museo, sin almacenar también su ubicación geográfica precisa. Esta explosión de información sobre nuestra tierra es fácilmente visible en nuevos desarrollos en que muchas empresas están trabajando y perfeccionando, como es un buen ejemplo Google Earth.

Es justamente esta gran proliferación de sistemas tanto convencionales como geográficos lo que ha generado un gran interés en la integración de los mismos. En general los primeros requerimientos involucrados en un proceso de integración se basan en factores como evitar ambiguedades en los datos, el aprovechamiento de la información ya recopilada, proveer una vista más amplia de toda la información que existe en una organización, etc. Sin embargo, comenzar un proceso de integración de datos incluso dentro de una organización es todo un desafío que no es fácil de lograr.

Con esto en mente, desde hace más de diez años muchos investigadores han comenzado a trabajar en soluciones para lograr la integración de los datos. Así surge el concepto de Sistemas Federados que incluye todas aquellas acciones que se deben realizar para que varios sistemas de información que son autónomos, heterogéneos y están distribuidos trabajen juntos como si fueran uno solo.

En esta tesis proponemos una novedosa solución que apunta a ayudar y mejorar

el proceso de integración de los datos. Está dirigida a brindar soporte a los desarrolladores de sistemas federados que deben iniciar un proceso de integración de varios sistemas de información involucrando también información espacial. El sistema que proponemos, denominado GeoMergeP, el cual se basa en una arquitectura basada en capas y en un proceso de integración, ayudará a los desarrolladores a simplificar problemas comunes como posibles ambiguedades e inconsistencias generadas al integrar varios sistemas. El sistema GeoMergeP se construye en base a dos procesos de integración, *enriquecimiento semántico* y *mezcla*, que brindan un soporte semi-automático a la creación de una vista integral del sistema federado resultante. El uso de los estándares para la información geográfica y la representación formal de ontologías como herramienta fundamental para proporcionar información semántica, brindan ventajas esenciales para generar una integración consistente.

Abstract

Nowadays, there exists a great expansion of information systems available within an organization or even on the Web. In general, several of these systems involve geographic information to represent common instances of the real-world. It is very common to think of representing information about a place, such as a particular house or museum, without thinking of storing also their precise geographic locations. In addition, the huge number of enterprises providing geographic services on the Web along with the new developments in GIS, such as Google Earth, show the growing availability of information about the Earth.

This proliferation of both conventional and geographic information systems have caused a great interest towards integration. Requirements involved in any integration process are focused on aspects such as avoiding ambiguities in data, taking advantage of stored information, providing a more general view of distributed information, etc. However, an integration process is not as simple as joining several systems, aspects such as modifiability and evolution must be taken into account. Thus, beginning an integration process is a complex challenge to be faced.

Having this in mind, for more that ten years several research groups in the world have been working on solutions to reach integration of data. Thus, the concept of Federated Systems emerged involving the actions to be performed to make autonomous, heterogeneous, and distributed systems work together.

In this thesis, we propose a novel solution aimed at helping and improving the data integration process. This solution provides support to developers of federated systems

who are responsible for starting an integration of several spatial information systems. We propose a system, called GeoMergeP, based on a layer-based architecture and an integration process which simplify common problems such as detecting ambiguities and inconsistencies generated during the construction of a federated system. The GeoMergeP system is built by using two main processes as a basis: the *semantic enrichment* and the *merging* processes. Both provide a semi-automatic support during the construction of an integral view of the resultant integrated system. The use of standard information to represent the geographic features, and the formal representation of ontologies as semantic resources to understand the meaning of the information, are crucial to generate a consistent integration.

Bibliografía

[1] Gdf - geographic data files standard version 3.0 (european standard). European Committee for Standardization (CEN/278), 1995.

[2] Atkis - amtliches topographisch-kartographisches informationssystem - objektartenkatalog (in german). Arbeitsgemeinschaft der Vermessungsverwaltungen (AdV), 1998.

[3] Geographic information. Reference Model, International Standard 19101, ISO/IEC, 2002.

[4] Geographic information. Spatial Schema. International standard 19107, ISO/IEC, 2003.

[5] Open gis consortium. OpenGIS Reference Model. OpenGIS Project Document 03-040, 2003.

[6] Geographic information. Rules for Application Schema. Draft International Standard 19109, ISO/IEC, 2005.

[7] Geographic information. Geography Markup Language (GML). Draft International Standard 19136, ISO/IEC, 2007.

[8] Aerts, K., Maesen, K., and Van Rompaey, A. A practical example of semantic interoperability of large-scale topographic databases using semantic web technologies. In *Proceedings of the AGILE'06: 9th Conference on Geographic Information Science* (Visegrád, Hungary, 2006), pp. 35–42.

[9] Avison, D. Information systems development: A broader perspective. In *Proceedings of the IFIP TC8 Working Conference on Method Engineering: Principles of method construction and tool support* (Chapman-Hall, London, 1996), R. W. S. Brinkkemper, K. Lyytinen, Ed., pp. 263–277.

[10] Baader, F., Calvanese, D., McGuiness, D., Nardi, D., and Patel-Schneider, P., Eds. *The Description Logic Handbook - Theory, Implementation and Applications*. Cambridge University Press, United Kingdom, 2003.

[11] Baskerville, R., and Wood-Harper, T. A critical perspective on action research as a method for information systems research. *Journal of Information Technology 11*, 3 (1996), 235–246.

[12] Berardi, D., Calvanese, D., and Giacomo, G. D. Reasoning on uml class diagrams. *Artificial Intelligence 168*, 1 (2005), 70–118.

[13] Biron, P., and Malhotra, A. Xml schema part 2: Datatypes. W3C Recommendation, 2001. Available at http://www.w3.org/TR/xmlschema-2/.

[14] Borges, K., Davis, C., and Laender, A. Omt-g: An object-oriented data model for geographic applications. *Geoinformatica 5*, 3 (2001), 221–260.

[15] Buccella, A. Integración de datos en base a ontologías e información contextual. Master's thesis, Universidad Nacional del Sur, Bahia Blanca, 2005.

[16] Buccella, A. Geographic information integration. Technical Report FDI2009, Computer Science Department. University of Comahue, http://giisco.uncoma.edu.ar/, enlace Federated Database Integration. Neuquen, Argentina, 2009.

[17] Buccella, A., and Cechich, A. Towards integration of geographic information systems. *Electronic Notes in Theoretical Computer Science 168* (2007), 45–59.

[18] Buccella, A., and Cechich, A. Ontology-driven geographic integration: Current approaches and future trends. In *Encyclopedia of Database Technologies and Appli-*

cations, Second Edition (To appear 2008), V. Ferraggine, J. Doorn, and L. Rivero, Eds., Idea Group.

[19] Buccella, A., Cechich, A., and Brisaboa, N. R. A federated layer to integrate heterogeneous knowledge. In *VODCA'04 First International Workshop on Views on Designing Complex Architectures* (Bertinoro, Italy, 2004), no. 142 in Electronic Notes in Theoretical Computer Science, Elsevier Science B.V, pp. 79–97.

[20] Buccella, A., Cechich, A., and Brisaboa, N. R. A three-level approach to ontology merging. In *MICAI'05: Fourth Mexican International Conference on Artificial Intelligence* (Monterrey, México, 2005), LNCS 3789, Springer-Verlag, pp. 80–89.

[21] Buccella, A., Cechich, A., and Fillotrani, P. Ontology-driven geographic information integration: A survey of current approaches. *Computers & Geosciences Special Issue on Geoscience Knowledge Representation in Cyberinfrastructure* (2008).

[22] Buccella, A., Gendarmi, D., Lanubile, F., Semeraro, G., Cechich, A., and Colagrossi, A. A layered ontology-based architecture for integrating geographic information. In *Studies in Computational Intelligence Series* (2008), Kacprzyk and Janusz, Eds., vol. 134, Springer-Verlag, pp. 135–144.

[23] Burrough, P., and McDonnell, R. *Principles of Geographical Information Systems*. Oxford University Press, 1998.

[24] Busse, S., Kutsche, R., Leser, U., and Weber, H. Federated information systems: Concepts, terminology and architectures. Tech. Rep. Nr. 99-9, Technical University of Berlin, 1999.

[25] Calefato, F., Colagrossi, A., Gendarmi, D., Lanubile, F., and Semeraro, G. An information broker for integrating heterogeneous hydrologic data sources: A web services approach. In *Research and Practical Issues of Enterprise Information System, IFIP Series (Springer)* (2006), A. Xu, L. Chaudhry, and S. Guarino, Eds., vol. 205.

[26] Calì, A. Reasoning in data integration systems: Why lav and gav are siblings. In *Proceedings of the ISMIS'03: 14th International Symposium on Methodologies for Intelligent Systems* (2003), Lecture Notes in Computer Science 2871, pp. 562–571.

[27] Calì, A., Calvanese, D., Giacomo, G. D., and Lenzerini, M. On the expressive power of data integration systems. In *Proceedings of the ER'02: 21st International Conference on Conceptual Modeling* (Tampere, Finland, 2002), Lecture Notes in Computer Science 2503, Springer, pp. 338–350.

[28] Calvanese, D., and Giacomo, G. D. Data integration: A logic-based perspective. *Artificial Intelligence Magazine 26*, 1 (2005), 59–70.

[29] Calvanese, D., Giacomo, G. D., and Lenzerini, M. A framework for ontology integration. In *Proceedings of the SWWS'01: 1st Semantic Web Working Symposium at the Emerging Semantic Web* (Stanford University, Palo Alto, CA, USA, 2001), pp. 303–316.

[30] Calvanese, D., Giacomo, G. D., and Lenzerini, M. Identification constraints and functional dependencies in description logics. In *IJCAI* (2001), pp. 155–160.

[31] Casati, R., Smith, B., and Varzi, A. C. Ontological tools for geographic representation. In *Formal Ontology in Information Systems* (Amsterdam, 1998), N. Guarino, Ed., IOS Press, pp. 77–85.

[32] Chalupsky, H. Ontomorph: A translation system for symbolic logic. In *Proceedings of the KR'00: 7th International Conference on Principles of Knowledge Representation and Reasoning* (Breckenridge, CO, USA, 2000), pp. 471–482.

[33] Chandrasekaran, B., Josephson, J. R., and Benjamins, V. R. What are ontologies, and why do we need them? *IEEE Intelligent Systems 14*, 1 (1999), 20–26.

[34] Chen, P. The entity-relation model- toward a unified view of data. *ACM Transaction on database systems 1*, 1 (March 1976), 9–36.

[35] Chrisman, N. R. Topological Information Systems for Geographic Representation. In *In Proceedings of the Second International Symposium on Computer-Assisted Cartography (Auto-Carto 2)* (Falls Church, 1975), pp. 346–351.

[36] Chrisman, N. R. Concepts of Space as a Guide to Cartographic Data Structures. In *In Proceedings of the First International Advanced Study Symposium on Topological Data Structures for Geographic Information Systems* (Cambridge, Massachusetts, 1978), pp. 1–19.

[37] Clark, T., and Evans, A. Foundations of the Unified Modeling Language. In *Proceedings of the 2nd BCS-FACS Northern Formal Methods Workshop* (Ilkley, UK, 23-24 September 1997).

[38] Codd, E. A relational model of data for large shared data banks. *Communications of the ACM 13*, 6 (1970), 377–387.

[39] Cohn, A. G., and Hazarika, M. Qualitative spatial representation and reasoning: An overview. *Fundamenta Informaticae 46*, 1-2 (2001), 1–29.

[40] Cui, Z., and O'Brien, P. Domain Ontology Management Environment. In *Proceedings of the 33rd Hawaii International Conference on System Sciences* (2000), IEEE.

[41] De Brujin, J. Using ontologies: Enabling knowledge sharing and reuse on the semantic web. Technical Report DERI-2003-10-29, DERI - Digital Enterprise Research Institute, Galway, Ireland, 2003.

[42] Euzenat, J., and Shvaiko, P. *Ontology Matching*. Springer-Verlag, Heidelberg, Germany, 2007.

[43] Evans, A. Reasoning with uml class diagrams. In *Proceedings of the WIFT '98: Second IEEE Workshop on Industrial Strength Formal Specification Techniques* (Washington, DC, USA, 1998), IEEE Computer Society, p. 102.

[44] Fagin, R., Kolaitis, P. G., Miller, R. J., and Popa, L. Data exchange: Semantics and query answering. In *Proceedings of the ICDT'03: International Conference on Database Theory* (Siena, Italy, 2003), pp. 207–224.

[45] Fensel, D. *Ontologies: Silver Bullet for Knowledge Management and Electronic Commerce*, 2nd edition ed. Springer-Verlag, Berlin, Germany, 2003.

[46] Fonseca, F. *Ontology-driven Geographic Information Systems.* PhD Dissertation, University of Maine, Orono, ME, USA, 2001.

[47] Fonseca, F., Davis, C., and Câmara, C. Bridging ontologies and conceptual schema in geographical information integration. *Geoinformatica 7*, 4 (2003), 307–321.

[48] Fonseca, F., Egenhofer, M., Agouris, P., and Câmara, C. Using ontologies for integrated geographic information systems. *Transactions in GIS 6*, 3 (2002), 231–257.

[49] Fowler, M., and Scott, K. *UML distilled (2nd ed.): a brief guide to the standard object modeling language.* Addison-Wesley Longman Publishing Co., Inc., Boston, MA, USA, 2000.

[50] Friedman, M., Levy, A., and Millstein, T. Navigational plans for data integration. In *Proceedings of the AAAI/IAAI'99: 16th National Conference on Artificial Intelligence and 11th Innovative Applications of Artificial Intelligence* (Menlo Park, CA, USA, 1999), American Association for Artificial Intelligence, pp. 67–73.

[51] Gendarmi, D., Lanubile, F., Lichelli, O., Semeraro, G., and Colagrossi, A. Water protection information management by syntactic and semantic interoperability of heterogeneous repositories. In *Proceedings of the ISESS'07: 12th International Symposium on Environmental Software Systems* (2007).

[52] Goh, C. H. *Representing and Reasoning about Semantic Conflicts in Heterogeneous Information Sources.* PhD Dissertation, MIT, Massachusetts Institute of Technology, Sloan School of Management, 1996.

[53] Goh, C. H. *Representing and reasoning about semantic conflicts in heterogeneous information systems*. PhD thesis, 1997. Supervisor-Stuart E. Madnick.

[54] Gomez-Perez, A., Corcho, O., and Fernandez-Lopez, M. *Ontological Engineering: with examples from the areas of Knowledge Management, e-Commerce and the Semantic Web. First Edition (Advanced Information and Knowledge Processings)*. Springer-Verlag, Berlin, Heidelberg, 2004.

[55] Grossman, M., Aronson, J., and McCarthy, R. V. Does uml make the grade? insights from the software development community. *Information & Software Technology 47*, 6 (2005), 383–397.

[56] Gruber, T. A translation approach to portable ontology specifications. *Knowledge Acquisition 5*, 2 (1993), 199–220.

[57] Guarino, N., and Welty, C. A formal ontology of properties. In *Proceedings of the EKAW'00: 12th European Workshop on Knowledge Acquisition, Modeling and Management* (London, UK, 2000), Lecture Notes in Computer Science 1937, Springer-Verlag, pp. 97–112.

[58] Guarino, N., and Welty, C. *An Overview of OntoClean*. Springer, 2004, ch. 8, pp. 151–172.

[59] Haarslev, V., Lutz, C., and Moller, R. Foundation of spatiotemporal reasoning with description logics. In *Proceedings of the KR'98: 6th International Conference on Principles of Knowledge Representation and Reasoning* (Trento, Italy, 1998), Morgan Kaufmann, pp. 112–123.

[60] Haarslev, V., and Möller, R. Racer system description. In *Proceedings of the IJCAR '01: 1st International Joint Conference on Automated Reasoning* (London, UK, 2001), Lecture Notes in Computer Science 2083, pp. 701–706.

[61] Hakimpour, F. *Using Ontologies to Resolve Semantic Heterogeneity for Integrating Spatial Database Schemata*. PhD Dissertation, Zurich University, Switzerland, 2003.

[62] Hakimpour, F., and Geppert, A. Global schema generation using formal ontologies. In *Proceedings of the ER'02: 21st International Conference on Conceptual Modeling* (2002), Lecture Notes in Computer Science 2503, pp. 307–321.

[63] Harmon, J., and Anderson, S. *The Design and Implementation of Geographic Information Systems*. John Wiley & Sons, 2003.

[64] Hasselbring, W. Information system integration. *Communications of the ACM 43*, 6 (2000), 32–38.

[65] Hess, G.Ñ., and Iochpe, C. Ontology-driven resolution of semantic heterogeneities in gdb conceptual schemas. In *Proceedings of the GEOINFO'04: VI Brazilian Symposium on GeoInformatics* (Campos do Jordão, Brazil, 2004), pp. 247–263.

[66] Horrocks, I., Sattler, U., and Tobies, S. Practical reasoning for expressive description logics. In *LPAR '99: Proceedings of the 6th International Conference on Logic Programming and Automated Reasoning* (London, UK, 1999), H. Ganzinger, D. McAllester, and A. Voronkov, Eds., no. LNAI 1705, Springer-Verlag, pp. 161–180.

[67] ISO/IEC. ISO 19103 Geographic Information: Conceptual schema language, 2005. International Standard.

[68] Jang, S., and Kim, T. J. Modeling an interoperable multimodal travel guide system using the iso 19100 series of international standards. In *Proceedings of the GIS '06: 14th annual ACM international symposium on Advances in geographic information systems* (New York, NY, USA, 2006), ACM Press, pp. 115–122.

[69] Janowicz, K. Extending semantic similarity measurement by thematic roles. In *Proceedings of the GeoS'05: First International Conference on GeoSpatial Semantics* (Mexico City, Mexico, 2005), Springer Verlag, pp. 137–152.

[70] Kalfoglou, Y., and Schorlemmer, M. Ontology mapping: the state of the art. *The Knowledge Engineering Review 18*, 1 (2003), 1–31.

[71] Katifori, A., Halatsis, C., Lepouras, G., Vassilakis, C., and Giannopoulou, E. Ontology visualization methods: A survey. *ACM Computing Surveys 39*, 4 (2007), 10:1–10:42.

[72] Kavouras, M., Kokla, M., and Tomai, E. Comparing categories among geographic ontologies. *Computers & Geosciences, Special Issue 31*, 2 (2003), 145–154.

[73] Kifer, M., Lausen, G., and Wu, J. Logical foundations of object-oriented and frame-based languages. *Journal of the Association for Computing Machinery (ACM) 42*, 4 (1995), 741–843.

[74] Klein, M. Combining and relating ontologies: an analysis of problems and solutions. In *Proceedings of the IJCAI'01: 17th International Joint Conferences on Artificial Intelligence* (Seattle, WA, USA, 2001), pp. 53–62.

[75] Laurini, R., and Thompson, D. *Fundamentals of spatial informations systems.* The APIC Series N 37, Academic Press, 1992.

[76] Levenshtein, I. V. Binary codes capable of correcting deletions, insertions, and reversals. *Soviet Physics Doklady 10* (1966), 707–710.

[77] Lin, D. An information-theoretic definition of similarity. In *Proceedings of the Fifteenth International Conference on Machine Learning* (1998), pp. 296–304.

[78] Longley, P., Goodchild, M., Maguire, D., and Rhind, D. *Geographic Information Systems and Science.* John Wiley & Sons, 2001.

[79] Luaces, M. R. *A Generic Architecture for Geographic Information Systems.* PhD thesis, Univerdade da Coruña, 2004.

[80] Madhavan, J., Bernstein, P. A., and Rahm, E. Generic schema matching with cupid. In *Proceedings of the VLDB '01: 27th International Conference on Very Large Data Bases* (San Francisco, CA, USA, 2001), Morgan Kaufmann Publishers Inc., pp. 49–58.

[81] Maedche, A., and Staab, S. Measuring similarity between ontologies. In *Proceedings of the EKAW'02 13th International Conference on Knowledge Engineering and Knowledge Management. Ontologies and the Semantic Web* (London, UK, 2002), Springer-Verlag, pp. 251–263.

[82] Magnini, B., Speranza, M., and Girardi, G. A semantic-based approach to interoperability of classification. hierarchies: Evaluation of linguistic techniques. In *Proceeding of COLING-2004* (Geneva, Switzerland, 2004).

[83] Mark, D. M., Skupin, A., and Smith, B. Features, objects, and other things: Ontological distinctions in the geographic domain. In *Proceedings of the COSIT'01: International Conference on Spatial Information Theory* (Berlin, 2001), Lecture Notes in Computer Science 2205, Springer-Verlag, pp. 488–502.

[84] Miller, G. A. Wordnet: A lexical database for english. *Communication of the ACM 38*, 11 (1995), 39–41.

[85] Noy, N. F., and McGuiness, D. L. Ontology development 101: A guide to creating your first ontology. Technical Report KSL-01-05 and SMI-2001-0880, Stanford Knowledge Systems Laboratory and Stanford Medical Informatics, Stanford University, Palo Alto, CA, USA, 2001.

[86] Noy, N. F., and Musen, M. A. Prompt: Algorithm and tool for automated ontology merging and alignment. In *Proceedings of the Seventeenth National Conference on Artificial Intelligence and Twelfth Conference on Innovative Applications of Artificial Intelligence* (2000), AAAI Press / The MIT Press, pp. 450–455.

[87] Ozsu, M. T., and Valduriez, P. *Principles of distributed database systems.* Prentice-Hall, Inc., Upper Saddle River, NJ, USA, 1991.

[88] Parent, C., Spaccapietra, S., and Zimányi, E. Spatio-temporal conceptual models: data structures + space + time. In *Proceedings of the GIS '99: 7th ACM International Symposium on Advances in Geographic Information Systems* (New York, NY, USA, 1999), ACM Press, pp. 26–33.

[89] Rahm, E., and Bernstein, P. A. A survey of approaches to automatic schema matching. *Very Large Data Bases Journal: 10*, 4 (2001), 334–350.

[90] Renz, J. *Qualitative Spatial Reasoning with Topological Information*. Lecture Notes in Computer Science 2293. Springer-Verlag, New York, NY, USA, 2002.

[91] Renz, J. Qualitative spatial and temporal reasoning: Efficient algorithms for everyone. In *Proceedings of the IJCAI'07: 20th International Joint Conference on Artificial Intelligence* (Hyderabad, India, 2007), pp. 526–531.

[92] Rigaux, P., Scholl, M., and Voisard, A. *Spatial Databases With Application To GIS*. Academic Press, 2001.

[93] Rodríguez, M., and Egenhofer, M. Comparing geospatial entity classes: An asymmetric and context-dependent similarity measure. *International Journal of Geographical Information Science 18*, 3 (2004), 229–256.

[94] Roger, S., Buccella, A., Cechich, A., and Palomar, M. Asematch: A semantic matching method. In *TSD'06: Ninth International Conference on Text, Speech and Dialogue* (Brno, Czech Republic, 2006), to appear.

[95] Rumbaugh, J., Jacobson, I., and Booch, G., Eds. *The Unified Modeling Language reference manual*. Addison-Wesley Longman Ltd., Essex, UK, UK, 1999.

[96] Schwering, A., and Raubal, M. Spatial relations for semantic similarity measurement. In *Proceedings of the ER'05: 24th International Conference on Conceptual Modeling* (2005), Lecture Notes in Computer Science 3770, Springer Berlin/Heidelberg, pp. 259–269.

[97] Shekhar, S., Coyle, M., Goyal, B., Liu, D., and Sarkar, S. Data models in geographic information systems. *Communications of the ACM 40*, 4 (1997), 103–111.

[98] Sheth, A. P., and Larson, J. A. Federated database systems for managing distributed, heterogeneous and autonomous databasess. *ACM Computing Surveys 3*, 22 (1990), 183–236.

[99] Shvaiko, P., and Euzenat, J. A survey of schema-based matching approaches. *Journal on Data Semantics IV* (2005), 146–171.

[100] Simons, A., and Graham, I. 30 things that go wrong in object modelling with uml 1.3. In *Behavioral Specifications of Businesses and Systems*, H. Kilov, B. Rumpe, and I. Simmonds, Eds. Kluwer, Dordrecht, 1999, pp. 221–242.

[101] Smith, B., and Mark, D. Ontology and geographic kinds. In *Proceedings of the International Symposium on Spatial Data Handling* (Vancouver, Canada, 1998), pp. 308–320.

[102] Sotnykova, A., Vangenot, C., Cullot, N., Bennacer, N., and Aufaure, M. Semantic mappings in description logics for spatio-temporal database schema integration. *Journal on Data Semantics III* (2005), 143–167.

[103] Stoimenov, L., Stanimirovic, A., and Djordjevic-Kajan, S. Discovering mappings between ontologies in semantic integration process. In *Proceedings of the AGILE'06: 9th Conference on Geographic Information Science* (Visegrád, Hungary, 2006), pp. 213–219.

[104] Su, X., Hakkarainen, S., and Brasethvik, T. Semantic enrichment for improving systems interoperability. In *Proceedings of the SAC '04: ACM symposium on Applied computing* (New York, NY, USA, 2004), ACM, pp. 1634–1641.

[105] Tun, N.Ñ. Semantic enrichment in ontologies for matching. In *Proceedings of the AOW '06: Second Australasian workshop on Advances in ontologies* (Darlinghurst, Australia, Australia, 2006), Australian Computer Society, Inc., pp. 91–100.

[106] Tversky, A. Features of similarity. *Psychological Review 84*, 4 (1977), 327–352.

[107] Visser, P., Jones, D., Bench-Capon, T., and Shave, M. An analysis of ontology mismatches; heterogeneity versus interoperability. In *Proceedings of the AAAI'97: Spring Symposium on Ontological Engineering* (1997), pp. 164–172.

[108] Visser, U. *Intelligent Information Integration for the Semantic Web*. Lecture Notes in Computer Science 3159. Springer, Heidelberg, Germany, 2004.

[109] Visser, U., and Schlieder, C. Modelling with ontologies. In *Proceedings of the Ontology and Modeling of Real Estate Transactions in European Juristictions* (Ashgate, 2002).

[110] Wache, H., Vögele, T., Visser, U., Stuckenschmidt, H., Schuster, G., Neumann, H., and Hbner, S. Ontology-based integration of information - a survey of existing approaches. In *Proceedings of the IJCAI'01: 17th International Joint Conferences on Artificial Intelligence* (Seattle, WA, 2001), pp. 108–117.

[111] Weibel, S., Gridby, J., and Miller, E. Oclc/ncsa metadata. Tech. rep., Dublin, EUA, 1995. http://www.oclc.org:5046/oclc/research/conferences/metadata/dublin_core_report.html.

[112] Wiederhold, G. An algebra for ontology composition. In *Proceedings of the Monterey Workshop on Formal Methods* (Monterey, CA, USA, 1994), pp. 56–61.

[113] Wood-Harper, T. Research methods in information systems: Using action research. In *Research Methods in Information Systems* (North-Holland, 1985), E. Mumford, R. Hirschheim, G. Fitzgerald, and A. Wood-Harper, Eds., Elsevier Science Publishers B.V., pp. 169–191.

[114] Worboys, M. F. *GIS: A Computing Perspective*. Taylor & Francis, 1995.