A Bibliography on Temporal Databases

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1 Introduction

This bibliography is an update of a 1986 bibliography (McKenzie, E. *Bibliography: Temporal Databases, ACM SIGMOD Record*, 15, No. 4, Dec. 1986, pp. 40-52), which was in turn an update of a 1982 survey (Bolour, A., T.L. Anderson, and H.K.T. Wong, *The Role of Time in Information Processing: A Survey, SIGArt Newsletter*, 80, April 1982, pp. 28-48) This bibliography consists of papers published or accepted for publication since the previous bibliography, as well as older papers that have not appeared in these previous surveys.

The pre-1982 survey, covering 1960-1982, contained 16 papers specifically relating time to database management, with 5 appearing in journals. The McKenzie bibliography, covering the next five years (1982-1986), listed over 80 papers on this subject, with 10 appearing in journals. This bibliography, covering the next 21 months (Jan. 1987 through September, 1988), lists over 100 papers, with 18 appearing in journals. During this period, the first conference on the topic was held (TAIS: Conference on Temporal Aspects in Information Systems, May, 1987). Our conclusion is that the field is growing rapidly and seems to be maturing, as more papers appear in journals (Figure 1 illustrates that the growth remains exponential).
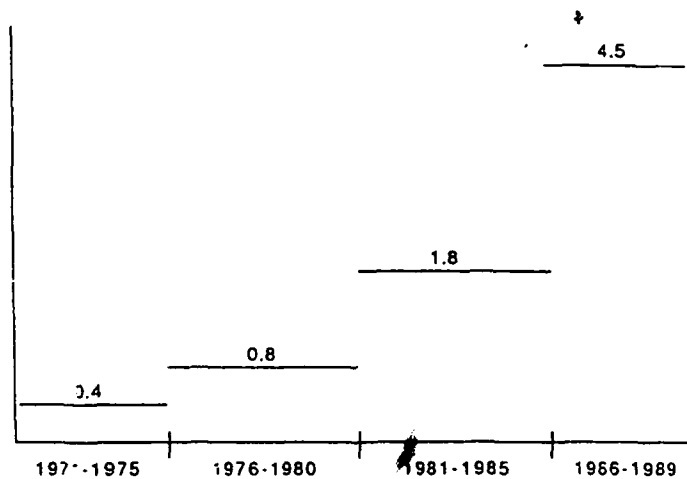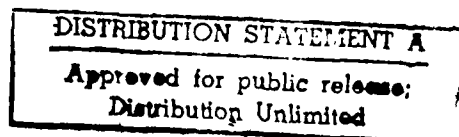

Figure 1: Average Number of Journal Papers Appearing Annually

The entries in this bibliography are classified according to a taxonomy of time in databases developed by Snodgrass and Ahn (*Temporal Databases*, *IEEE Computer*, 19, No. 9, September, 1986, pp. 35-42.) Papers that propose augmenting conventional database management systems to represent *transaction time* (that is, the time when information is entered into a database) are listed in Section 2. Papers that propose augmenting conventional database management systems to represent *valid time* (that is, the time that information models in the real world) are listed in Section 3. Finally, papers that propose augmenting conventional databases with both aspects of time are listed in Section 4.

2 Transaction Time

As defined above, transaction time concerns the time when data is entered into the database. Relations that contain transaction time are termed *rollback* relations.

Abiteboul, S. and V. Vianu. *Transactions and Integrity Constraints*, in *Proceedings of the ACM Symposium on Principles of Database Systems*. 1985, pp. 193-204.

Abiteboul, S. and V. Vianu. *Deciding Properties of Transactional Schemas*, in *Proceedings of the ACM Symposium on Principles of Database Systems*. 1986, pp. 235-239.

Abiteboul, S. and V. Vianu. *A Transaction Language Complete for Database Update and Specification*, in *Proceedings of the ACM Symposium on Principles of Database Systems*. San Diego, CA: Mar. 1987.

Adiba, M.E. and N. Bui Quang. *Dynamic Database Snapshots, Albums, and Movies*, in *Proceedings of the Conference on Temporal Aspects in Information Systems*. AFCET. France: May 1987, pp. 207-225.

Barbic, F. and R. Maiocchi. *Planning in Time*, in *Proceedings of the Conference on Temporal Aspects in Information Systems*. AFCET. France: May 1987, pp. 147-165.

Bjork, L.A., Jr. *Generalized Audit Trail Requirements and Concepts for Data Base Applications*. *IBM Systems Journal*, 14, No. 3 (1975), pp. 229-245.

Blanken, H. and A. Ijbema. *Language Concepts for Versioned Hierarchical Objects*, in *Proceedings of the Conference on Temporal Aspects in Information Systems*. AFCET. France: May 1987, pp. 191-207.

Brodie, M. *On Modelling Behavioral Semantics of Databases*, in *Proceedings of the Conference on Very Large Databases*. Cannes, France: Sep. 1981, pp. 32-42.

Casanova, M.A. and A.L. Furtado. *On the Description of Database Transition Constraints Using Temporal Languages*, in *Advances in Database Theory*, *Vol. II*. Ed. H. Gallaire, J. Minker and J.-M. Nicolas. New York: Plenum Press, 1984. Vol. II. pp. 211-236.

Ceri, S., G. Pelagatti and G. Bracchi. *Structured Methodology for Designing Static and Dynamic Aspects of Data Base Applications*. *Information Systems*, 6, No. 1 (1981), pp. 31-45.

Chou, H.-T. and W. Kim. *A Unifying Framework for Version Control in a CAD Environment*, in *Proceedings of the Twelfth International Conference on VLDB*. 1986.

Dietz, J.L.G. and K.M. van Hee. *A Framework for the Conceptual Modeling of Discrete Dynamic Systems*, in *Proceedings of the Conference on Temporal Aspects in Information Systems*. AFCET. France: May 1987, pp. 61-81.

Dittrich, K.R. and R.A. Lorie. *Version Support for Engineering Database Systems*. Technical Report RJ 4769. IBM. July 1985.

Easton, M.C. *Key-Sequence Data Sets on Indelible Storage*. Research Report RJ 4778 (50637). IBM Research Laboratory. July 1985.

Katz, R.H., M. Anwaruddin and E. Chang. *A Version Server for Computer-Aided Design Data*, in *23rd Design Automation Conference Proceedings*. ACM/IEEE. Las Vegas, NV: June 1986.

Kent, W. *Versions of Versioning*. Technical Report. Hewlett-Packard Laboratories. 1987.

Kimball, K.A. *The DATA System*. Master's Thesis, University of Pennsylvania, 1978.

Klahold, P., G. Schlageter and W. Wilkes. *A General Model for Version Management in Databases*, in *Proceedings of the Twelfth International Conference on VLDB*. 1986.

Lausen, G. *Analyse und Steuerung Paralleler Transaktionen in Einem Versionen-Datenbanksystem*. PhD. Diss. Karlsruhe, FRG, 1982.

LePape, C. and S.F. Smith. *Management of Temporal Constraints for Factory Scheduling*, in *Proceedings of the Conference on Temporal Aspects in Information Systems*. AFCET. France: May 1987, pp. 165-177.

Lindsay, B., L. Haas, C. Mohan, H. Pirahesh and P. Wilms. *A Snapshot Differential Refresh Algorithm*, in *Proceedings of ACM-SIGMOD*. Association for Computing Machinery. Washington DC: May 1986.

Lingat, J.Y., P. Nobecourt and C. Rolland. *Behaviour Management in Database Applications*, in *Proceedings of the Conference on Very Large Databases*. Ed. P. Hammersley. Brighton, England: Sep. 1987, pp. 185-196.

Lipeck, U.W. and G. Saake. *Monitoring Dynamic Integrity Constraints Based on Temporal Logic*. *Information Systems*, 12, No. 3 (1987), pp. 255-269.

McKenzie, E. and R. Snodgrass. *Scheme Evolution and the Relational Algebra*. Technical Report TR87-003. Computer Science Department, University of North Carolina at Chapel Hill. May 1987.

McKenzie, E. and R. Snodgrass. *Extending the Relational Algebra to Support Transaction Time*, in *Proceedings of ACM SIGMOD International Conference on Management of Data*. Ed. U. Dayal and I. Traiger. Association for Computing Machinery. San Francisco, CA: May 1987, pp. 467-478.

Mueller, T. and D. Steinbauer. *Eine Sprachschnittstele zur Versionenkontrolle in CAM-Datenbanken*, in Informatik-Fachberichte. Berlin: Springer, 1983. pp. 76-95.

Navathe, S.B. and R. Ahmed. *Temporal Aspects of Version Management. Database Engineering*, 7, No. 4, Dec. 1988, pp. 34-37.

Oberweis, A. and G. Lausen. *On the Representation of Temporal Knowledge in Office Systems*, in *Proceedings of the Conference on Temporal Aspects in Information Systems*. AFCET. France: May 1987. pp. 131-146.

Saake, G. and U.W. Lipeck. *Foundations of Temporal Integrity Monitoring, in Temporal Aspects in Information Systems.* Ed. C. Rolland, F. Bodart and M. Leonard. North-Holland, 1988. pp. 239-246.

Sarin, S.K., C.W. Kaufman and J.E. Somers. *Using History Information to Process Delayed Database Updates,* in *Proceedings of the Conference on Very Large Databases.* Ed. Y. Kambayashi. Kyoto, Japan: Aug. 1986, pp. 71-78.

Schueler, B. *Update Reconsidered,* in *Architecture and Models in Data Base Management Systems.* Ed. G. M. Nijssen. North Holland Publishing Co., 1977.

Verma, V. and H. Lu. *A New Approach to Version Management for Databases,* in *Proceedings of the AFIPS National Computer Conference.* Chicago, IL: AFIPS Press, June 1987, pp. 645-651.

Vianu, V. *Dynamic Constraints and Database Evolution,* in *Proceedings of the ACM Symposium on Principles of Database Systems.* Association for Computing Machinery. Atlanta, GA: Mar. 1983. pp. 389-399.

Weikum, G. *Entwurfsueberlegungen fuer Einen Versionen-Manager zur Realisierung eines Temporalen Daten-banksystems.* Technical Report DVSI-1983-A1. Darmstadt, FRG. 1983.

Zhenhe, G. and C. Kung. *On Temporal Aspect of Database Specifications. Sci. Sin. A. Math. Phys. Astron. Tech. Sci. (China),* 30, No. 10, Oct. 1987, pp. 1102-12.

3   Valid Time

Valid time concerns the time when the information was valid in the real world. Relations that include valid time are termed *historical relations.*

Adiba, M.E. and N. Bui Quang. *Historical Multi-media Databases,* in *Proceedings of the Conference on Very Large Databases.* Ed. Y. Kambayashi. Kyoto, Japan: Aug. 1986, pp. 63-70.

Bassiouni, M.A. and M. Llewellyn. *Handling Time in Query Languages,* in *Proceedings of Statistical and Scientific Database Management Conference.* Rome: June 1988.

Blum, R.L. *Displaying Clinical Data from a Time-Oriented Database. Comput. Biol. Med.,* 11, No. 4 (1981), pp. 197-210.

Castillo, I.M.V., M.A. Casanova and A.L. Furtado. *A Temporal Framework for DataBases,* in *Proceedings of the Conference on Very Large Databases.* 1982.

Chaudhuri, S. *Temporal Relationships in Databases,* in *Proceedings of the Conference on Very Large Databases.* Los Angeles, California: Aug. 1988.

Chen, K. *The Inductive Acquisition of Temporal Knowledge.* Technical Report ISG 86-14. Department of Computer Science, University of Illinois at Urbana-Champaign. 1986.

Clifford, J. and A. Croker. *The Historical Relational Data Model (HRDM) and Algebra Based on Lifespans,* in *Proceedings of the International Conference on Data Engineering.* IEEE Computer Society. Los Angeles, CA: IEEE Computer Society Press, Feb. 1987, pp. 528-537.

Clifford, J. and A. Rao. *A Simple, General Structure for Temporal Domains.* in *Proceedings of the Conference on Temporal Aspects in Information Systems.* AFCET. France: May 1987, pp. 23-30.

Clifford, J. and A. Croker. *Objects in Time.* Database Engineering, 7, No. 4, Dec. 1988, pp. 11-18.

Date, C.J. *A Proposal for Adding Date and Time Support to SQL.* ACM SIGMOD Record, 17, No. 2, June 1988, pp. 53-76.

De, S., S. Pan and A. Whinston. *Temporal Semantics and Natural Language Processing in a Decision Support System.* Information Systems, 12, No. 1 (1987), pp. 29-47.

Ferg, S. *Modeling the Time Dimension in an Entity-Relationship Diagram,* in *4th International Conference on the Entity-Relationship Approach.* IEEE. Silver Spring, MD: Computer Society Press, 1985, pp. 280-286.

Fiadeiro, J. and A. Sernadas. *Behavioral Aspects of Intelligent Knowledge-based Information Systems,* in *Proceedings of the Conference on Temporal Aspects in Information Systems.* AFCET. France: May 1987, pp. 81-99.

Gadia, S.K. *The Role of Temporal Elements in Temporal Databases.* Database Engineering, 7, No. 4, Dec. 1988, pp. 19-25.

Gadia, S.K. *A Homogeneous Relational Model and Query Languages for Temporal Databases.* ACM Transactions on Database Systems, 13, No. 4, Dec. 1988.

Gadia, S.K. and C.-S. Yeung. *Inadequacy of Interval Time Stamps in Temporal Databases.* To appear in *Information Sciences,* (1988).

Garnic, D.K., A.T. Cohen and H.A. Sowisral. *Timestamping in Virtual Time Systems,* in *Proceedings of the Conference on Temporal Aspects in Information Systems.* AFCET. France: May 1987, pp. 225-239.

Jones, S. and P.J. Mason. *Handling the Time Dimension in a Data Base,* in *Proceedings of the International Conference on Data Bases.* Ed. S.M. Deen and P. Hammersley. British Computer Society. University of Aberdeen: Heyden, July 1980, pp. 65-83.

Lee, R.M. *A Denotational Semantics for Administrative Databases,* in *Proceedings of the IFIP WG 2.6 Working Conference on Data Semantics (DS-1).* Ed. T.B. Steel and R. Meersman. IFIP. Hasselt, Belgium: Jan. 1985, pp. 83-120.

Lorentzos, N.A. and R.G. Johnson. *TRA: A Model for a Temporal Relational Algebra,* in *Temporal Aspects in Information Systems.* Ed. C. Rolland, F. Bodart and M. Leonard. North Holland, 1987, pp. 203-215.

Lorentzos, N.A. and R.G. Johnson. *Extending Relational Algebra to Manipulate Temporal Data.* Internal Report NL/1/87. Department of Computer Science, Birkbeck College, London University. Aug. 1987.

Lorentzos, N.A. *A Formal Extension of the Relational Model for the Representation and Manipulation of Generic Intervals.* PhD. Diss. Birkbeck College, London University, Aug. 1988.

Lorentzos, N.A. and R.G. Johnson. *An Extension of the Relational Model to Support Generic Intervals,* in *Advances in Database Technology - EDBT'88.* Ed. J.W. Schmidt, S. Ceri and M. Missikoff. Springer-Verlag, 1988, pp. 528-542.

Lorentzos, N.A. and R.G. Johnson. *Requirements Specification for a Temporal Extension to the Relational Model* Database Engineering, 7, No. 4, Dec. 1988, pp. 26-33.

Lorentzos, N.A. and R.G. Johnson. *Extending Relational Algebra to Manipulate Temporal Data.* To appear in *Information Systems*, 13, No. 3 (1988).

Lorentzos, N.A. and V.J. Kollias. *The Handling of Depth and Time Intervals in Soil Information Systems. To appear in Computers and Geosciences*, (1988).

McKenzie, E. and R. Snodgrass. *Supporting Valid Time: An Historical Algebra.* Technical Report TR87-008. Computer Science Department, University of North Carolina at Chapel Hill. Aug. 1987.

McKenzie, E. and R. Snodgrass. *An Evaluation of Historical Algebras.* Technical Report TR87-020. Computer Science Department, University of North Carolina at Chapel Hill. Oct. 1987.

Moens, M. *Temporal Databases and Natural Language*, in *Proceedings of the Conference on Temporal Aspects in Information Systems.* AFCET. France: May 1987, pp. 177-191.

Navathe, S.B. and R. Ahmed. *TSQL-A Language Interface for History Databases*, in *Proceedings of the Conference on Temporal Aspects in Information Systems.* AFCET. France: May 1987, pp. 113-128.

Navathe, S.B. and R. Amed. *A Temporal Relational Model and a Query Language. To appear in Information Sciences: An International Journal*, (1988).

Sadeghi, R. *A Database Query Language for Operations on Historical Data.* PhD. Diss. Dundee College of Technology, Dec. 1987.

Sadeghi, R., W.B. Samson and S.M. Deen. *HQL — A Historical Query Language.* Technical Report. Dundee College of Technology. Sep. 1987.

Sarda, N.L. *Modelling of Time and History Data in Database Systems*, in *Proceedings CIPS Congress 87 Winnipeg.* CIPS. May 1987, pp. 15-20.

Sarda, N.L. *Design of an Information System using a Historical Database Management System*, in *Proceedings of International Conference on Information Systems.* CIPS. Dec. 1987, pp. 86-96.

Sarda, N.L. *Algebra and Query Language for a Historical Data Model. To appear in The Computer Journal*, (1988).

Sarda, N.L. *Design of a Historical Database Management System.* Technical Report. Division of Math, Engr, and Computer Science, University of New Brunswick, Saint John, N. B. Canada. 1988.

Studer, R. *A Conceptual Model for Time.* in *Proceedings of the Sixth International Conference on Entity-Relationship Approach.* The ER Institute. New York, NY: Nov. 1987.

Tansel, A.U. *Adding Time Dimension to Relational Model and Extending Relational Algebra. Information Systems*, 11, No. 4 (1986), pp. 343-355.

Tansel, A.U. and M.E. Arkun. *HQUEL, A Query Language for Historical Relational Databases*, in *Proceedings of the Third International Workshop on Statistical and Scientific Databases.* July 1986, pp. 135-142.

Tansel, A.U. and M.E. Arkun. *Aggregation Operations in Historical Relational Databases*, in *Proceedings of the Third International Workshop on Statistical and Scientific Databases*. July 1986, pp. 116-121.

Tansel, A.U. *A Statistical Interface for Historical Relational Databases*, in *Proceedings of the International Conference on Data Engineering*. IEEE Computer Society. Los Angeles, CA: IEEE Computer Society Press. Feb. 1987, pp. 538-546.

Tansel, A.U. *A Historical Query Language. To appear in Information Sciences: An International Journal*, (1988).

Tansel, A.U. *Non First Normal Form Temporal Relational Model. Database Engineering*, 7, No. 4. Dec. 1988. pp. 46-52.

Tansel, A.U., M.E. Arkun and G. Ozsoyoglu. *Time-By-Example Query Language for Historical Databases. To appear in IEEE Transactions on Software Engineering*, (1989).

4   Both Transaction and Valid Time

Since transaction time and valid time are orthogonal aspects, it is possible to include both, resulting in a *temporal relation*.

Adiba, M.E., N. Bui Quang and J. Palazzo de Oliveira. *Time Concept in Generalized Data Bases*, in *ACM Annual Conference*. Association for Computing Machinery. Denver, Colorado: Oct. 1985. pp. 214-223.

Adiba, M.E. *Histories and Versions for Multimedia Complex Objects. Database Engineering*, 7. No. 4. Dec. 1988. pp. 3-10.

Ahn, I. and R. Snodgrass. *Partitioned Storage for Temporal Databases. Information Systems.* 13, No. 4 (1988).

Ahn, I. and R. Snodgrass. *Performance Analysis of Temporal Queries. To appear in Information Sciences*, July 1989.

Ariav, G. *Handling The Time Dimension in ISs - A Research Agenda*. Technical Report 81-12-02. University of Pennsylvania. February 1982.

Ariav, G. and J. Clifford. *Temporal Data Management: Models and Systems*, in New Directions for Database Systems. Norwood, New Jersey: Ablex Publishing Corporation, 1986. Chap. 12. pp. 168-185.

Ariav, G. *Design Requirements for Temporally Oriented Information Systems*, in *Proceedings of the Conference on Temporal Aspects in Information Systems*. AFCET. France: May 1987, pp. 9-23.

Bui Quang, N. *Notion de Temps Dans les Bases de Donnees Generalisees*. Rapport de Dea Imag. IMAG Grenoble Univ France. June 1984.

Bui Quang, N. *Gestion des Historiques Pour la Base de Donnees Generalisees TIGRE*. R.R. TIGRE IMAG. IMAG Grenoble Univ France. June 1985.

Bui Quang, N. *Dynamic Aspects and Time Management in Generalized Database Systems*. PhD. Diss. Institut National Polytechnique de Grenoble, Nov. 1986.

Carmo, J. and A. Sernadas. *A Temporal Logic Framework for a Layered Approach to Systems Specification and Verification*, in *Proceedings of the Conference on Temporal Aspects in Information Systems*. AFCET. France: May 1987, pp. 31-47.

Chen, P.P.S. *The Time Dimension in the Entity-Relationship Model*, in *IFIP Information Processing 1986*. Ed. H.-J. Kugler. North-Holland, 1986.

Fagan, L.M. *VM: Representing Time-Dependent Relations in A Medical Setting*. PhD. Diss. Stanford University. June 1980.

Fugini, M.G., R. Maiocchi and R. Zicari. *Time Management in the Office-net System*, in *IFIP WG8.4 Workshop on Office Knowledge*. Toronto, Canada: Aug. 1987.

Gadia, S.K. and C.S. Yeung. *A Generalized Model for a Relational Temporal Database*, in *Proceedings of ACM SIGMOD International Conference on Management of Data*. Association for Computing Machinery. Chicago, Illinois: June 1988, pp. 251-259.

Gunadhi, H. and A. Segev. *Physical Design of Temporal Databases*. Technical Report LBL-24578. Lawrence Berkeley Lab. 1988.

Knolmayer, G. *Die Beruecksichtigung des Zeitbezugs von Daten bei der Gestaltung computer-gestuetzter Informationssysteme (Considering Time Aspects of Data in the Development of Computer-based Information Systems)*. Technical Report 215. Institut fuer Betriebswirtschaftslehre, D-23 Kiel, Olshausenstrasse 40, Germany. May 1988.

Martin, N.G., S.B. Navathe and R. Ahmed. *Dealing with Temporal Schema Anomalies in History Databases*, in *Proceedings of the Conference on Very Large Databases*. Ed. P. Hammersley. Brighton, England: Sep. 1987, pp. 177-184.

McKenzie, E. *Bibliography: Temporal Databases. ACM SIGMOD Record*, 15, No. 4, Dec. 1986, pp. 40-52.

McKenzie, E. *An Algebraic Language for Query and Update of Temporal Databases*. PhD. Diss. Computer Science Department, University of North Carolina at Chapel Hill, Sep. 1988.

Rolland, C., F. Bodart and M. Leonard (eds). *Proceedings of the Conference on Temporal Aspects in Information Systems*. North Holland, May 1987.

Rotem, D. and A. Segev. *Physical Organization of Temporal Databases*, in *Proceedings of the International Conference on Data Engineering*. IEEE Computer Society. Los Angeles, CA: IEEE Computer Society Press, Feb. 1987, pp. 547-553.

Segev, A. and A. Shoshani. *Logical Modeling of Temporal Data*, in *Proceedings of the ACM SIGMOD Annual Conference on Management of Data*. Ed. U. Dayal and I. Traiger. Association for Computing Machinery. San Francisco, CA: ACM Press, May 1987, pp. 454-466.

Segev, A. and A. Shoshani. *Modeling Temporal Semantics*, in *Temporal Aspects in Information Systems*. Ed. F. Bodart C. Rolland, M. Leonard. North-Holland, 1988. pp. 47-58.

Segev, A. and A. Shoshani. *The Representation of a Temporal Data Model in the Relational Environment*, in *Proceeding of the 4th International Conference on Statistical and Scientific Database Management*. 1988.

Segev, A. and A. Shoshani. *Functionality of Temporal Data Models and Physical Design Implications. Database Engineering*, 7, No. 4, Dec. 1988, pp. 38-45.

Shoshani, A. and K. Kawagoe. *Temporal Data Management*, in *Proceedings of the Conference on Very Large Databases*. Kyoto, Japan: Aug. 1986, pp. 79-88.

Snodgrass, R. *The Temporal Query Language TQuel. ACM Transactions on Database Systems*. 12 No. 2 June 1987, pp. 247-298.

Snodgrass, R., S. Gomez and E. McKenzie. *Aggregates in the Temporal Query Language TQuel.* TempIS Technical Report 16. Computer Science Department, University of North Carolina at Chapel Hill. July 1987.

Snodgrass, R. (ed.) *Research Concerning Time in Databases: Project Summaries. ACM SIGMOD Record*, 15. No. 4, Dec. 1986, pp. 19-39.

Tasker, D. *An Entity-Relationship View of Time*, in *Proceedings of the Sixth International Conference on Entity-Relationship Approach*. The ER Institute. New York, NY: Nov. 1987.

Thirumalai, S. and S. Krishna. *Data Organization for Temporal Databases*. Technical Report. Raman Research Institute. 1988.