

Emerging Data Warehousing Technologies By the beginning of this century, the foundational concepts of data warehouse systems were mature and consolidated. The amount of spatial data available is growing considerably due to technological advances in areas such as remote sensing and global navigation satellite systems (GNSS), namely the Global Positioning System (GPS) and the Galileo system. In addition, since the sequences generated by moving objects' positions can be very long, they are often processed by being divided into segments of movement called trajectories, which are the unit of interest in the analysis of movement data. The basic layer of the data representation for the semantic web recommended by the World Wide Web Consortium (W3C) is the Resource Description Framework (RDF), on top of which the Web Ontology Language (OWL) is based. In a semantic web scenario, domain ontologies (defined in RDF or some variant of OWL) define a common terminology for the concepts involved in a particular domain. The NewSQL and HTAP paradigms, Data lakes, Delta Lake, Polyglot architectures, and cloud data warehouses are responses to this demand from academia and industry. An alternative approach to this problem is based on the notion of Temporal databases, which provide structures and mechanisms for representing and managing time-varying information. The common approach to address this situation consists of modifying the data in the warehouse to comply with the new version of the schema: this implies removing data that are no longer needed and adding new data that were not previously collected. Over the years, spatial data has been increasingly used in various areas, such as public administration, transportation networks, environmental systems, and public health, among others. Since connectedness is naturally modeled by graphs, the interest in graph databases and graph analytics lead to the notion of graph data warehousing and graph OLAP. On the one hand, the property graph data model is used for native graph databases and graph analytics, where graph data structures composed of nodes and vertices are the basis for storing the data. What is needed is to extend the traditional OLAP operators for exploring time-varying data, which is referred to as temporal OLAP (TOLAP). As an answer to these challenges, distributed storage and processing, NoSQL database systems, column-store database systems, and in-memory database systems are part of new emerging data warehouse architectures. The need to combine structured, unstructured, and real-time analytics demands for solutions that can integrate data analysis in a single system. Spatial data warehouses provide improved data analysis, visualization, and manipulation. Semantic annotations are especially useful for describing unstructured, semistructured, and textual data.