Spatial Monitoring of Cattle – Impact on the Carbon Cycle

Camilo Carromeu[1,2], Claudia Bauzer Medeiros[1]

[1]Institute of Computing - IC, P.O.Box 6176, University of Campinas – UNICAMP, 13083-970, Campinas, SP, Brazil

[2]Faculty of Computing - FACOM, P.O.Box 549, Federal University of Mato Grosso do Sul – UFMS, 79070-900, Campo Grande, MS, Brazil
camilo@ufms.br, cmbm@ic.unicamp.br

Abstract. There is a growing demand for accurate information about the real environmental impact caused by cattle, accompanied by a concern for increased production of cattle related products in a sustainable manner. With the widespread adoption of RFID chips for bovine traceability and new technologies for measuring carbon dioxide in the atmosphere, it is now feasible to develop carbon cycle models that combine such factors. This presents challenges that range from data management to model specification and validation, to correlate animal movements and their impact on different biomes. This paper presents a proposal towards this goal, concerned with the creation of a framework to store and index semantic space trajectories of livestock to enable monitoring of the production of CO_2.

1 INTRODUCTION

In Brazil, the beef cattle industry encompasses approximately 172 million hectares distributed in more than 5.1 million establishments, with an estimated 170 million cattle, according to the 2006 Agriculture Census[1]. The country has the 2nd largest commercial herd in the world, is the largest exporter and the second in an equivalent amount of carcass produced, behind only the United States. Approximately 140 countries now buy Brazilian beef (Luchiari 2006). The livestock industry therefore plays an important role in the economy.

To remain the largest exporter of beef in the world, Brazil should invest in developing technological solutions to ensure the quality of the meat. The Ministry of Agriculture established the Integrated Farming Production System (SAPI) for the livestock food supply chain. SAPI is a system marked by sustainable farming operation in accordance with the formal protocols of Good Agricultural Practices[2], to ensure high quality and safety, both for

[1] http://www.ibge.gov.br/english/estatistica/economia/agropecuaria/censoagro/2006/ (2010-09-18)
[2] http://bpa.cnpgc.embrapa.br/ (2010-09-18)

agro-foods, as well as for its products, agro industrial by-products and wastes (Mota et al. 2005).

Geographic traceability (the result of the association of geographical information to data used in a traceability scheme) is a key prerequisite in SAPI and similar systems (Kondo et al. 2007). It allows the identification of the individual animal from birth to slaughter, recording its location and keeping track of events of interest throughout its life. Traceability is a concept that involves several types of activities and refers to the ability to describe and to follow the life of a conceptual or physical element, preserving its identity and its origins.

This article presents our initial effort in establishing a computational infrastructure to help monitor and understand environmental changes caused by cattle, and its influence on biomes. This infrastructrure will rely on novel geographic databases for tracking moving objects for analysis and monitoring applied to the beef supply chain. Our research concerns modeling and design of spatiotemporal databases to allow the correlation of cattle trajectories, traceability information and environmental data.

2 RELATED WORK

Most scientific papers on agricultural traceability ignore implementation aspects and are concentrated on logistics, or certification. More recently, work has appeared concerning a computer science perspective (Kondo et al. 2007) (Baccarin 2009). At the same time, several initiatives are appearing to develop systems to support traceability and supply chain quality. One such example is the e-SAPI *bovis* system, developed by a partnership of Embrapa Beef Cattle partnered with the Federal University of Mato Grosso do Sul. This system relies on a spatial database that contains geographic traceability information for each individual animal. This is achieved by an infrastructure that combines information from RFID chips in each individual which is traced via georeferenced antennae that record the passage of these individuals (Carromeu et al. 2009).

At the same time, the GIS community has developed intensive research on moving objects and spatio-temporal databases. However, it is only in the last 3 years that trajectories have been studied under a semantic context, e.g., (Yan et al. 2010) (Alvares et al. 2007) (Gómes and Vaisman 2009) (Mouza and Rigaux 2005) (Yan et al. 2008) (Wessel, Luther and Moller 2009). Of particular interest to our work is the research on semantic trajectories of (Spaccapietra et al. 2008) and related work, whereby events of interest are annotated to derive semantics from sets of trajectories. For example, Yan et al (2010) propose a hybrid model of semantic-space paths that abstracts data into layers, so that the lower layer contains the raw data of moving objects, captured by GPS embedded devices, and the uppermost layer contains the semantic trajectory.

Our goal is to relate trajectories with environmental data, to derive information on the influence of cattle in environmental changes. In this context, we can take advantage of an ongoing project, conducted jointly by Embrapa Beef Cattle and Embrapa Satellite Monitoring, which is being designed to evaluate the net contribution of carbon from beef cattle and milk in Brazil. The goal is to create a matrix that quantifies this contribution according to the biome and the production system, publishing a database with georeferenced areas of each biome and each production system (De Medeiros 2009). This can be used to provide us with data, though it is not concerned with space-time dynamics.

We also intend to profit from the Orbiting Carbon Observatory (OCO). This project, under development by NASA, will put into orbit an observatory equipped with a telescope that feeds three spectrometers capable of detecting the absorption of sunlight by carbon dioxide in Earth's atmosphere. Processing this information, OCO is capable of getting the concentration levels of this gas in regions of the Earth (Crisp et al. 2004).

3 Semantic Trajectory Model for Beef Cattle

The focus of our work is to design and implement a computational infrastructure that will allow monitoring environmental changes caused by cattle activities. The underlying spatiotemporal database will need to store information on moving subjects and regions that deform as a function of time, where data is collected and analyzed at different spatiotemporal granularities. Our database model will start from work on semantic trajectories, extending this work to accommodate animal movements. The starting point of this research is to use the e-SAPI *bovis* database, that will allow the identification of regions of greatest concentration of animals and the displacement of these populations.

The database of e-SAPI *bovis* contains raw data on animal movements, since it stores all the space-time events concerning the location of each animal in specific spatial locations defined by the antennae. Our model will start from these paths, i.e. individuals moving in and out of biomes and characterize groups of trajectories and moving regions, as well as regions that characterize gas concentrations.

Additional data will be provided by the ongoing project of (De Medeiros 2009), that will enable estimates of the total quantity of carbon dioxide produced in a given region. Moreover, one can compare these data with real information on the amount of gas in the specific region obtained from satellite data (Crisp et al. 2004).

Thus, the first stage of the project is the development of a model to map trajectories of each animal. Based on work by Yan et al (2010), we are designing a hybrid model of semantic-space trajectories that: (1) encapsulates spatiotemporal semantic information on rough handling of animals, (2) permits the progressive abstraction of data representation using high-level semantics and (3) extends concepts of semantic trajectories to allow the correlation of moving points and regions of both identifiable objects (cattle) and fuzzy regions (carbon dioxide) – e.g., the concept of “stop-move” (Spaccapietra et al. 2008). This, in turn, is requiring us to revisit work on the object vs field debate in the GIS community a decade ago.

The first level of abstraction of our data model is responsible for encapsulating the raw data handling. It is essentially a long sequence of spatiotemporal objects, represented by tuples collected at various time intervals. These tuples are aggregated into substrings that form meaningful units of the total movement, called “space-time trajectories”.

The second level of abstraction is the logical partitioning of a trajectory in a series of temporally separate non-overlapping “episodes”, to be semantically annotated, using ontologies, to give them meaning. Annotations can be cumulative and context-sensitive, so that a given episode can have as many annotations as there are needs for data interpretation.

Our data on animal movements is captured by fixed antennae, RFID readers, whose location was previously stored. These antennae are linked to “locals”, e.g., identified as farms or stores. Thus, it is possible to map the episodes and transform them semantic knowledge. Therefore, the model can be materialized in layers that are progressively responsible for abstracting the raw data collected.

While this can handle the data provided by individual moving objects, there still remains the problem of handling environmental data on moving phenomena. Hence, the next step will be to define a template that implements the matrix generation of carbon dioxide as a function of the biome and production system. We intend to adopt a multi-layered architecture that allows regions to be imported into the platform so that information about the biome and the production system are linked to each RFID antenna. Thus, a biome region bound by geographic coordinates will set this information on all the antennae in this region. As the location of each antenna is set, one can determine which antennae are in a particular area. The same process is applied to production systems.

The last step is data entry from OCO. Again, we will consider a multi-layered architecture that allows data import and conversion to the same georeferencing basis the data on the amount of CO_2 remaps geographic regions that provide information to the antennae contained in the region.

Once all data are stored and semantically annotated, we will proceed to design algorithms to perform animal-carbon emission correlations, with help from experts on environmental modeling.

4 Conclusion

This paper describes the initial steps of a project concerned with geo-changes. Since we are still in the beginning of the project, its main contributions lie in pointing out new research directions, as well as describing concrete data sources, already available, that can be taken advantage of to meet the project challenges. In particular, the proposal presents a study for the creation and application of models, algorithms and techniques in databases whose space-time spatial data are captured through fixed points and georeferenced RFID chips in the entities or technologies embedded GPS.

Besides contributing to research on traceability and all its benefits for production and sanitary control, the focus of this research is to obtain a model that can confront spatial data from various sources and distinct spatio-temporal granularities in order to correlate animal movements with CO_2 concentration, thereby establishing the influence of cattle on biomes. This will contribute to the area of spatio-temporal databases, as well as provide a computational basis for geo-change research. The model will contemplate both abstract and concrete pathways that enter and leave geo-referenced regions, which in turn undergo deformations as a function of time.

The infrastructure will be applied to the beef supply chain, investigating its real impact on the environment and ways to increase production while providing health guarantees and quality. It may also be used as in the surveillance by competent organs, e.g., to compare the number of animals declared in a property with the amount estimated by the CO_2 produced.

Since this is ongoing work, we have still not defined the appropriate annotation mechanism, and will have to construct appropriate domain ontologies to annotate trajectories. It is expected that these ontologies will include information from the Brazilian Geographic Institute (IBGE), as well as from other Brazilian institutions such as EMBRAPA.

Acknowledgements. This research was partially funded by CNPq, CAPES, FAPESP, project BioCORE (CNPq) and INCT on Web Science.

5 REFERENCES

Alvares, L. O., V. Bogorny, et al. (2007). “A Model for Enriching Trajectories with Semantic Geographical Information”. Proc. ACM-GIS.

Baccarin, E. (2009). “Automated Negotiation of Multi-party Contracts in Agricultural Supply Chains“. PhD Thesis, IC - UNICAMP.

Carromeu, C., C. O. Soares, et al. (2009). “e-SAPI *bovis*: Plataforma Web para Rastreabilidade Bovina”. Proceedings of the 7th Congresso Brasileiro de Agroinformática (SBIAgro 2009), Viçosa, MG.

Crisp, D., R. M. Atlas, et al. (2004). “The Orbiting Carbon Observatory (OCO) Mission”. Advances in Space Research, nº 34.

De Medeiros, S. R. (2009). “Estruturação de um Sistema de Gestão e Monitoramento Territorial da Produção Pecuária de Corte e Leite”. ‘Macro Program 3’ ongoing project of Embrapa Beef Cattle.

Gómez, L., A. Vaisman (2009). “Efficient Constraint Evaluation in Categorical Sequential Pattern Mining for Trajectory Databases”. Proc. EDBT 2009.

Kondo, A. A., Medeiros, C. B., Bacarin, E., and Madeira, E. R. (2007). “Traceability for Food in Supply Chains”. Proc of the 3rd Int Conf on Web Information Systems and Technologies (WEBIST 2007), 121-127.

Luchiari, A. (2006). “Produção de Carne Bovina no Brasil: Qualidade, Quantidade ou Ambas?”. Anais 2nd Simpósio sobre Desafios e Novas Tecnologias na Bovinocultura de Corte (SIMBOI 2006), Brasília, DF.

Mota, E. G., J. J. Ferreira, et al. (2005). “SAPI: Sistema Agropecuário de Produção Integrada”. Proceedings of the 1st Simpósio sobre Desafios e Novas Tecnologias na Bovinocultura de Corte (SIMBOI 2005), Brasília.

Mouza, C., P. Rigaux (2005). “Mobility Patterns”. GeoInformatica, v. 9, n. 4, p. 297-319, December.

Spaccapietra, S., C. Parent, et al. (2008). “A Conceptual View on Trajectories”. Data and Knowledge Engineering, 65, 126–146.

Yan, Z., C. Parent, et al. (2010). “A Hybrid Model and Computing Platform for Spatio-Semantic Trajectories”. LNCS 6088, 60-75.

Yan, Z., J. Macedo, et al. (2008). “Trajectory Ontologies and Queries”. Transactions in GIS, 12(s1), 75-91.

Wessel, M., M. Luther, R. Moller (2009). “What Happened to Bob? Semantic Data Mining of Context Histories”. Proc DL2009.