Recommender Systems using GIS: a review of the literature

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Abstract. The main contribution of this paper is to overview the current state of the research in the use of GIS as part of recommender systems. Although uses vary, special attention was given to agricultural applications. Besides fields of application, the type of algorithm used was also evidenced.

1. Introduction

Recommender systems using GIS are already a reality in some fields, such as tourism. In others, it is still in its first steps. Our main interest is agriculture, which, according to (PIERCE et al, 2007), "the GIS user community in production agriculture is rather small compared to other business sectors". Agriculture has a very specific set of requirements, which change largely based on climate, location, season, crop, soil quality and many other factors.

In this work, we will get a picture of the current state of development of recommender systems using GIS, and, to a smaller degree, recommender systems in agriculture generally. But first, we must define what are recommender systems and GIS:

1.1 Recommender Systems

As consumption shifts from the physical world to the Web, recommender systems tend to be regarded increasingly as an indispensable tool for commerce. A driving force for that is the shortening of the feedback loop on the digital world, as the Web permits users to give feedback about their purchases. Other forms of input are even easier to harvest: a user buying an item, or even just browsing it, may be seen as an endorsement of the item. The basic idea of recommender systems is to utilize these various sources of data to infer customer interests (AGGARWAL, 2016).

Increasing product sales is the ultimate goal of a recommender system in e-commerce. Businesses have a limited amount of space to expose potential customers to ads, and the effective use of this element-in-scarcity is of great importance. Recommender systems help companies to deliver a taylor-made ad to specific potential customers, with a probable increase in sales.

In very general terms, recommender systems' algorithms fall into two categories: if it uses metadata and information of the profile of users, it is called content-based filtering; on the other hand, if it uses usage data, it is called collaborative filtering. Literature also has included a third category, of hybrid systems, that use characteristics of both of the previous kinds. (FALK, 2019).

1.2 Geographic Information System

GIS is a type of database (or an extension to an existing database, i.e. PostGIS) that is able to store geographical data in meaningful ways (enabling users to visualize, manipulate, analyze and manage these data). Even though there are non-relational spatial databases, most are relational (OBE et al, 2021).

As put by (PIERCE et al, 2007), agriculture is ideally suited for GIS applications, because it

1) is natural resource based;

2) requires the manipulation of large quantities of goods;

3) is required to record details of business operations from the field to the marketplace.

2. **Methodology**

The main question we looked to answer in our analysis was "How can recommender systems be associated with GIS to deliver location-based recommendations?"

Papers dealing specifically with GIS-based recommender systems for agriculture are rather rare, so it was opted to look for two kinds of papers:

1) those who used recommender systems with GIS; and, to a lesser degree

2) those who used recommender systems for agriculture, which could potentially give insights for future research with GIS added.

Papers were found mainly on Google Scholar, but also on ACM Digital Library and Springer Link. The search for this first batch of papers was simple, summarized on the following query:

recommender AND system AND (gis OR agriculture)

The appropriate adaptations were made when searching for other languages. Even though it was expected that most papers would use English, it was searched also for papers in French, Italian and Spanish, each yielding a few papers and/or thesis.

As the number of papers found were not abundant, it was decided not to be draconian on the exclusion of articles, and it was decided to refer also to recent thesis, if they were relevant enough. The process is explained in the next session.

The format of the paper and the organization of topics were loosely based on (MONTEIRO et al, 2021).

3. **Revision**

All papers were read integrally, and were accepted or reject on basis of:

1) Possibility to give insights on future works on GIS-based recommender systems;

2) The level of detail given on the methods used.

Criteria of inclusion were the relevance of the paper, its year of publication (earlier than 2007) and the originality of the application.

As for condition 2, all articles with less than 5 pages were excluded, as were most articles with less than 8 pages. Two thesis were analyzed, but were not included,

as their methods were also present in adopted papers. They are both referenced on the bibliography.

Table 1 summarizes the number of articles manipulated in this fashion:

Database	Initial papers	Rejected papers	Adopted papers
ACM	6	4	2
Google Scholar	38	23	15
Springer	8	5	3

4. **Results**

The papers vary widely in scope and goals, but are all united by the use of recommender systems with GIS, or, at least, in an agricultural environment. One simple way to divide them is to organize them by the kind of algorithm used by their recommender system. As we have seen in section 1, recommender algorithms are, in a very broad sense, divided in three categories, collaborative, content-based and hybrid. The adopted papers could be thus divided:

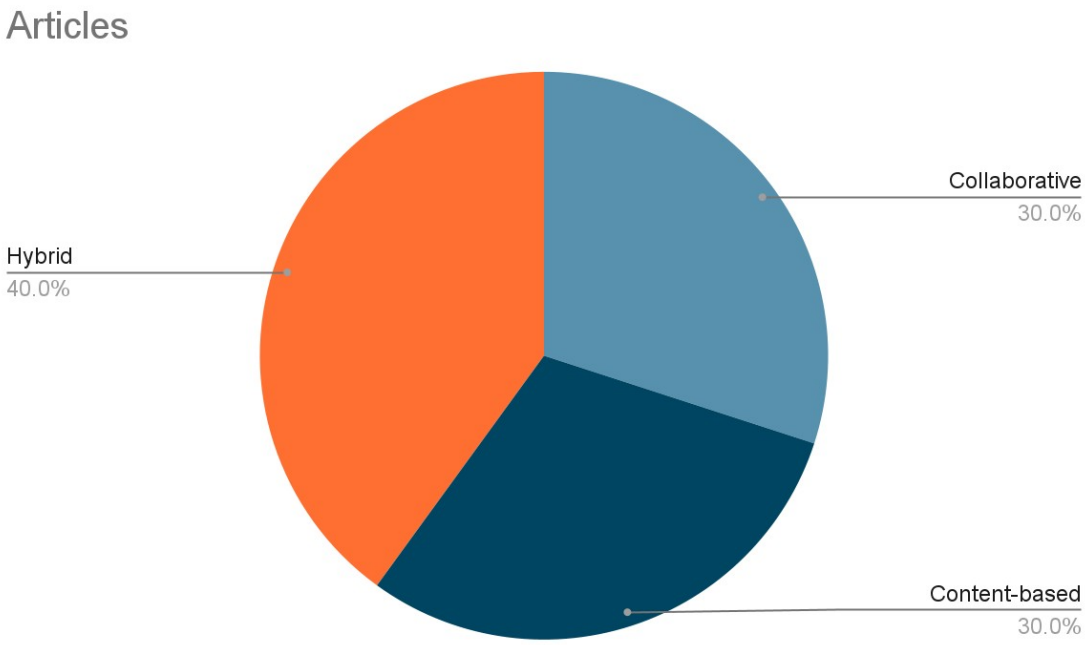

Fig. 1: Articles by type of recommender algorithm

Methods used within the recommender systems differ greatly based on the kind of use: an algorithm to suggest NPK fertilizers (CHOUGULE et al, 2019) would,

understandably, be very different from one to recommend routes with beautiful landscapes (KAWAY et al, 2009). Nevertheless, on the review of the articles, all the battle-hardened algorithms could be seen, for the most diverse uses, specially clustering with k-means and classification with k-nearest neighbors. Interestingly, no articles used, for classification, modern implementations of gradient boosting, such as XGBoost, which have become a staple in the industry for such problems.

Of this disparity of uses, our adopted papers could also be divided between fields of application, such as:

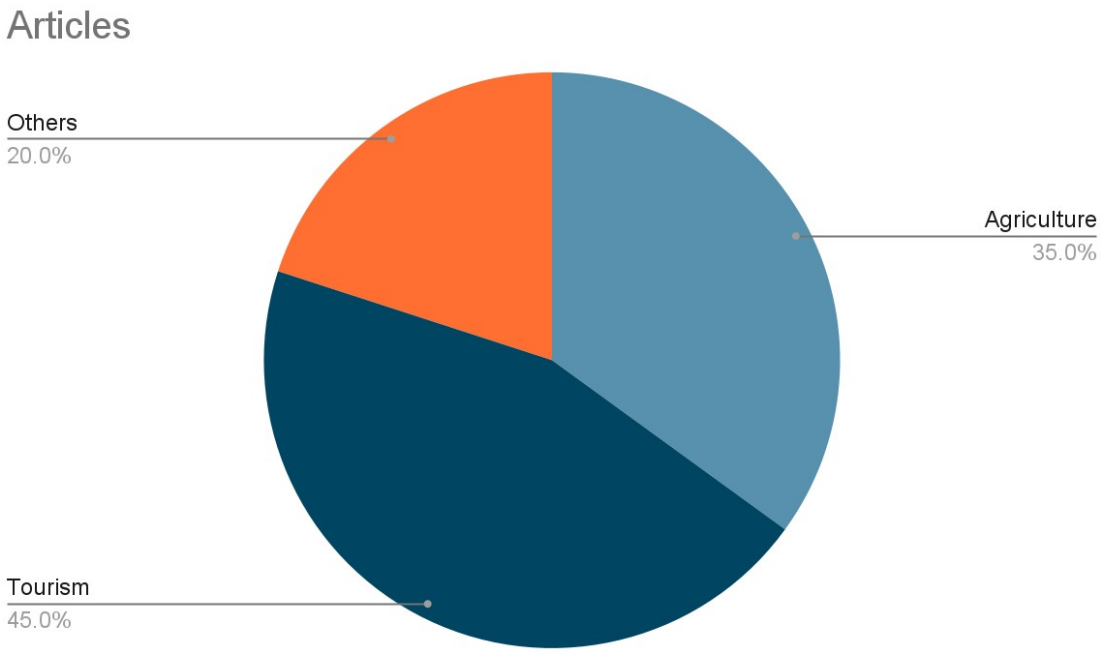

Fig. 2: Articles by field of application

Most articles, by the very criteria we adopted to accept or reject papers, would fall into two categories: agriculture, an a priori theme we wanted to explore, and tourism, as this is the most advanced field when combining recommender systems with GIS. The third category, others, would encompass rather interesting applications, such as restaurant suggestions within a city, and even suggestions of routes during a university campus visit.

4.1 Highlights from selected articles

Chougule et al, 2019	Crop Suitability and Fertilizers Recommendation Using Data Mining Techniques This papers describes the development of an ontology-based recommendation system for fertilizer recommendation. The interesting twinst is that it focus on NPK fertilizers, and

	the recommendation works on the levels of each micronutrient on this product (i.e. Nitrogen, Phosphorus and Potassium).
Otero et al, 2014	Esbozo de una técnica para la recomendación de productos turísticos en Cuba usando GIS An interesting take on the role of a recommender system using a collaborative algorithm to boost tourism in Cuba, as the nation's economy becomes more and more dependent on it. It shows, contrary to most papers we have seen, the mathematics behind the curtains.
Petit et al, 2010	Algorithme de recommandation adaptable pour la personnalisation d'un système mobile Shows the results of the development of a hybrid and adaptable recommender system to suggest routes on a campus visit. It uses implicit profiles created analyzing the preferences of the user. Written in Java, something not too common in this field.
Kumar et al, 2019	Development of a Model Recommender System for Agriculture Using Apriori Algorithm Although it does not use GIS, this paper shows the development of a cunning system: after an apriori algorithm estimates the production of agri-items, a recommender system suggests to customers what they could buy, basing it on a content-based engine.
Martinez et al, 2009	REJA: a georeferenced hybrid recommender system for restaurants This is a classical hybrid recommender system for restaurants, but making heavy use of spatial data for the city of Jaen, providing also an interface to marketing processes in e-commerce. This kind of interface between technique and marketing is quite relevant to us, as this is an unexplored area for recommenders in agriculture.
Jaiswal et al, 2020	Collaborative Recommendation Systems For Agriculture Sector (sic) A very creative recommendation system that

	suggests programs and benefits provided by the government of India to farmers. Under the hood, it uses k-nearest neighbors and cosine similarity to classify farmers into groups of similar profiles, to provide recommendations.
Kawai et al, 2009	Tour recommendation system based on web information and GIS Another cunning application of recommender systems tightly coupled with GIS: A path recommender só that tourists could take a route with a more pleasant landscape, or, as the authors put, “with beautiful scenic sights”. That means, beauty has a bigger impact than the shortest path or the avoidance of traffic jams.

5 Conclusions

As we spread our research to gather information on recommender systems, GIS and agriculture, we are left with several interesting insights waiting to be intertwined. Clearly, we lack research on this important field.

GIS in agriculture could have a large number of applications, from suggestions of crops that would be suitable on the region of the user, to which fertilizer a farmer should use, to specific ads a farmer could receive based on his crop, the time of the year and his location. Possibilities of use seem endless.

Recommender systems for agriculture are fundamentally different from those from, for example, e-commerce, as the profile of the user has a much smaller influence on his consumption habits, and his location has a much more strong influence than in e-commerce. Also, the time window for the selling of specific goods is much more tight in agriculture, as conditions change through the year.

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