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A new method to learn growth curves of beef cattle using a factorization approach

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ABSTRACT

The evolution of cattle weight is a very important issue for beef cattle breeders. The weights of the animals of a herd are usually available at different ages and it is intended to predict the trajectory that will follow the weight of each animal. In this paper, we address this problem as a Recommender System. In this case, the users would be the animals, and the items would be the ages of weight measurements. The values of the items would be the measured weights at a given age. As in Recommender Systems the aim is to complete the valuation matrix (weights) in an individualized way (that is, adapted to each animal). A matrix factorization system is devised to learn weights using all the available characteristics of the animals. The weights thus obtained are compared with a linear regression that adequately estimates the general evolution of the herd, but not the individual evolution of each animal. To illustrate the benefits of this approach, we used a real world dataset of cattle of the breed Avileña-Negra Ibérica and crossbreeding with sires of Charolais and Limousin.

1. Introduction

Live weight of beef cattle is the main feature affecting carcass performance and hence the incomes of breeders. Thus, the estimation of the weight of bovines as a function of time is very important for meat producers. Predicting growth can help breeders to decide the best time to slaughter in order to increase their economic benefits.

There are different approaches to study weight evolutions in the literature. In West et al. (2001) they propose a universal curve that describes the growth of many diverse species, transforming time and weight data to a common dimensionless scale. Live weight of bovines is often estimated from easily accessible morphometric characteristics (Enevoldsen and Kristensen, 1997; Coopman et al., 2009). Sometimes, to obtain the body measurements the authors use digital image processing (Stajnko et al., 2008; Tasdemir et al., 2011). In other cases, genetic information about animals it is also considered. A comparison of different genetics methods can be seen in Jaffrézic and Pletcher (2000). These methods try to obtain the capability of animals to transmit genetically the gain of weight to their progeny (Arango et al., 2004; Freetly et al., 2011).

In this paper, we use Machine Learning procedures to learn a model to predict weights of animals of *Avileña-Negra Ibérica*. We want to anticipate the weight of each single animal (Díez et al., 2003; Alonso et al., 2007; Alonso et al., 2013; Alonso et al., 2015). *Avileña-Negra Ibérica* is a beef breed of central Spain. Their carcasses are characterized by an intermediate muscle conformation (69.1%) and fatness level (12.6%) (Albertí et al., 2008). The market target of these carcasses is made up of those consumers that prefer tender meat but with an intense flavor (Díez et al., 2006). Due to calving ease, straightbred cows of *Avileña-Negra Ibérica* are used in crossbreeding programs with sires of *Charolais* and *Limousin* breeds.

The approach presented here is based on Matrix Factorization (MF). In recent years, MF techniques for machine learning have been attracting more and more attention, especially since a recommender system based on MF won the *Netflix* prize (Koren et al., 2009). MF algorithms were used in many application fields such as medical recommendations (Zhang et al., 2016), audience selection (Kanagal et al., 2013), text analysis (Ji and Eisenstein, 2014), or evaluating open-response assignments in Massive Open Online Courses (MOOCs) (Luaces et al., 2015a).

Dimensionality reduction is another important task of machine learning where MF is widely used. In this context, the purpose is to obtain a simplified lower-rank approximation of the original dataset. This allows presenting, possibly geometrically, the structure that may be inherent in a dataset, mainly the relationship between objects and their attributes. Dimensionality reduction with MF has been successfully applied in feature selection (Wang et al., 2015), image analysis (Khurana et al., 2015; Moon et al., 2016), to identifying user preferences (Luaces et al., 2015b) and in many other problems along with clustering techniques.

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Table 1
Representation of the data of our problem in matrix form.

	Age_1	Age_2	Age_3	Age_4	Age_5
Animal_1		220	290	340	
Animal_2	180		275		400
Animal_3		150	196	230	
Animal_4	210	258		389	460

We took advantage of matrix factorization techniques in two different ways. On the one hand, we develop an algorithm capable of predicting the evolution of animal weights with good accuracy. On the other hand, our system projects the information of animals in a Euclidean space with a reduced dimension. This embedding enables visualization and clustering of animals based on some trait, such as its growth potential.

Data in our problem are represented by means of a matrix in the same way as recommender systems do. In such systems, ratings of users about a kind of products are arranged in matrices. Users are laid out in rows, while products are set out in columns. Users only rate a small subset of the product database. Therefore, even the most popular items have very few ratings; thus the matrix has very low density. In our case, the entries of the matrix are the live weights of animals, the rows contain the information of each animal and the columns contain the information on the animal's age when the corresponding weight was taken. Since animals have been weighed only a few times at different ages we get a sparse matrix. We have to learn a function able to fill in the gaps of the matrix (weights missing at certain ages) with the least possible error. Our data would be similar to those shown in Table 1.

Both animals and ages are represented by feature vectors. These vectorial descriptions are essential for the proper performance of the system. They allow to establish differences between animals based on features such as sex, breed, body condition or birthing season. Moreover, descriptions can be enriched if needed with some new features of animals or ages.

It is important to emphasize that our method allows to obtain weight trajectories adapted to the specific data of each animal. Other systems, such as regression, only differentiate weight trajectories of the animals in a constant (specific to each animal). As a result, all the trajectories are parallel. This simplification implies the assumption that the weight of all animals increases in the same way, which is unacceptable.

2. Material and methods

2.1. Data

The dataset used in this study was obtained from several feedlots of *Avileña-Negra Ibérica* breed of cattle. This set contains two types of animals: purebred and crossbred animals. Crossbred animals are always from *Avileña-Negra Ibérica* mother and father from Charolais or Limousin breed. Information on each animal consists of its identification, origin, date of birth and live weight measured at different ages. Only animals that have 4 or more measurements were used because a significant sequence of weights is required in order to *learn* the way animals grow. Cattle are transferred to a feedlot at ages that range from 90 to 365 days. The number of animals and weights to work with are detailed in Table 2.

We would like to emphasize that available data on animals are quite diverse in several aspects:

- There are important differences in growth by sex and breed.
- Animals enter the feedlot at quite different ages.
- The ratio of weight to age varies considerably when cattle enter the feedlot.

Table 2
Description of the number of animals and weights divided by sex and father's breed.

Abbreviation	Father's breed	Sex	#Animals	#Weights
Avi_M	Avileña	Male	6353	32317
Avi_F	Avileña	Female	347	1730
Cha_M	Charolais	Male	1706	8258
Cha_F	Charolais	Female	1670	7741
Lim_M	Limousin	Male	481	2360
Lim_F	Limousin	Female	435	2072
		TOTAL	**10992**	**54478**

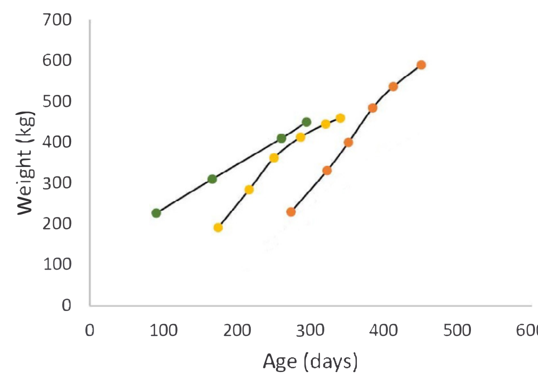

Fig. 1. Sample growth trajectories of animals showing differences in shape, slope and initial age (the age when animals enter the feedlot).

- Growth rates of animals are very different even if they have the same sex and breed.

This disparity complicates the learning task considerably. Fig. 1 shows weight curves of some animals to illustrate differences among them. It has been necessary to design a method capable to properly reflect all this variability.

2.2. Learning method

Let $\mathscr{A}$ be a set of *animals* and let $\mathscr{D}$ be a set of *ages* in which animals are weighted. Let us consider a partially defined matrix

$$\mathscr{M} = (m_{ij}:\ i \in \mathscr{A},\ j \in \mathscr{D}) \tag{1}$$

where m_{ij}, if available, is the live weight (in kilograms) of the animal i at the age j. Both animals and ages will be represented by vectors of features. These vectors are used to describe specific characteristics of the animals/ages. We explain this representation in more detail in Section 2.3.

Our main objective is to learn the weights of animals making use of matrix completion techniques. We look for a function

$$g\colon \mathscr{A} \times \mathscr{D} \to \mathbb{R} \tag{2}$$

to compute weights of animals at any age. In other words, we will learn a function g with the following general expression:

$$g(a, d) = \sum_{i,j} \alpha_{ij}\, a_i\, d_j. \tag{3}$$

This function is just a weighted sum of the products of the vectors representing animals and ages. So, the weight of an animal at a given age depends on all possible combinations of descriptors of animal i (a_i) and descriptors of age j (d_j). But this expression may have too many parameters to learn, the components of a matrix $\Lambda = (\alpha_{ij}\colon i, j)$. Thus, we search for a couple of matrices such that Λ can be *factorized* through them.