Deep Auto-Encoding for Context-Aware Inference of Preferred Items' Categories

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Keywords

Recommender Systems; Deep Learning; Auto-encoder; Context; Mobile

Abstract

Context-aware systems [1,4] enable the sensing and analysis of user context in order to provide personalized services to users. Contextual factors derived from the sensors on mobile devices can greatly improve context prediction accuracy. However, defining relevant contextual information for the application service is a challenging task. We observed that it is possible to automatically learn contextual factors and behavioral patterns when users interact with the system. We later utilize the learned patterns to infer contextual user interests within a recommender system. We present a novel context-aware model for detecting users' preferred items' categories using an unsupervised deep learning technique applied to mobile sensor data. We train an auto-encoder for each item genre, using contextual data that was obtained when users interacted with the system. Given new contextual sensor data from a user, the discovered patterns from each auto-encoder are used to predict the category of items that should be recommended to the user in the given context. In order to collect rich contextual data, we conducted an extensive field study over a period of four weeks with a group of ninety users. The analysis reveals significant insights regarding the inference of different granularity levels of categories that are available within the data. Our model significantly improves the classification accuracy by 16% to 73% compared with state-of-the-art classification methods. We also show how to utilize the deep architecture in order to handle the cold start problem and to determine the similarity between contexts in a recommender system.

When dealing with context, three entities can be distinguished: places (rooms, buildings etc.), people (individuals, groups), and things (physical objects, computer components etc.)[4]. Other studies [2,5,6] used additional aspects of context (e.g., time, surrounding objects and people, weather conditions) in order to benefit from the various digital footprints left by users in the digital world. However, in order to improve context prediction it is necessary to discard indiscriminative or highly correlated features

in order to avoid the curse of dimensionality [3]. In addition, when dealing with high dimensional data, it is important to consider dependencies between characteristics [7], in order to avoid a large number of model parameters. We suggest a novel approach for modeling users' context utilizing high dimensional data. We sense the user's rich contextual feature space and apply an unsupervised deep learning technique that extracts the most important features and discovers significant correlations between them. Our study focuses on modeling hidden context patterns from available data (e.g., Wi-Fi networks, accelerometers, light, microphones, etc.) sensed from the users' mobile devices. We add meaning and explanation to our unsupervised context patterns by splitting the data through different contextual user preferences as observed from users' interactions with a recommender system. This novel approach integrates unsupervised contexts and explicit interactions for the purpose of inferring contextual user preferences and recommendation timing from sensor data. The inferred contexts may add value to many user experience enhancement applications, specifically to CARS.

Our data was collected via an Android application where users provided positive and negative feedback regarding points of interest (POIs) that were recommended to them. For every instance of contextual user feedback, we recorded a rich set of sensor data from their mobile devices. We split the data to train and test sets and build models based on the contextual patterns of positive feedback for different categories of POIs. Each model is a neural network characterizing users' behavioral patterns that were observed while expressing a preference regarding a category of items. We used these models to predict users preferred category/genres of POIs at different levels of granularity and achieved significantly better results than state-of-the-art classification algorithms. Table 1 presents results for the three high level categories.

Table 1. Prediction of Three High Level Categories

Prediction Model	Accuracy	AUC
Auto-Encoding	**0.971**	**0.927**
C4.5 (Compact)	0.651	0.7
C4.5	0.668	0.751
Random Forest	0.657	0.739
Naïve Bayes	0.217	0.625

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