Chapter 75
Recurrent Neural Networks for Predicting Mobile Device State

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ABSTRACT

Nowadays, mobile devices are ubiquitous in modern life as they allow users to perform virtually any task, from checking e-mails to playing video games. However, many of these operations are conditioned by the state of mobile devices. Therefore, knowing the current state of mobile devices and predicting their future states is a crucial issue in different domains, such as context-aware applications or ad-hoc networking. Several authors have proposed to use different machine learning methods for predicting some aspect of mobile devices' future states. This chapter aims at predicting mobile devices' battery charge, whether it is plugged to A/C, and screen and WiFi state. To fulfil this goal, the current state of a mobile device can be regarded as the consequence of the previous sequence of states, meaning that future states can be predicted by known previous ones. This chapter focuses on using recurrent neural networks for predicting future states.

INTRODUCTION

Smartphones have become a key part of everyday life as an essential tool for their users. People have fully integrated mobile devices into their lives by using them to communicate with friends, check e-mails, play games, record physical activities and take pictures, among other possible uses. Moreover, smartphones are equipped with several features (WiFi, GPS, and Bluetooth among others) that can re-

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cord activities and contextual information, such as location, application usage, and even messaging and calling behaviour. Hence, smartphones are interesting options for tracking and mining user behaviour in daily life (Do and Gatica-Perez, 2014). This information offers new opportunities to analyse human behaviour aiming at enhancing the user experience with mobile devices and, at the same time, helping to ease the use of smartphones' services (Rios et al., 2014).

Several domains leverage on the prediction of mobile devices' states (Pejovic and Musolesi, 2015; Niroshinie et al., 2013; Ravi et al., 2008). For example, in the development of context aware applications, the predictions could be useful for determining the context in which applications are running. Such context aware applications are encompassed in a concept called "Anticipatory Mobile Computing" (AMC) (Pejovic and Musolesi, 2015). The goal of AMC is deciding which actions should be taken based on predicted future states to improve the outcome. AMC concepts are present in personal assistance technology (such as Google Now, Microsoft Cortana or Siri), healthcare applications and smart cities. Personal assistance technology uses state prediction to provide relevant information to the user before such information is requested. For example, predicting that the hour in which the user goes to work allows personal assistance technology to provide information about traffic and weather, which might be relevant to the user.

Other use of predictions can be found in mobile cloud computing (Niroshinie et al., 2013). One of its key proposals is moving computing from mobile devices to the cloud to reduce battery consumption. However, to effectively reduce battery consumption, it is necessary to predict whether the energy requirements for communicating are lower than those of processing. In addition, if the mobile device is not going to be connected to the Internet when the cloud finishes its work, computation results will be unavailable. This might lead to the repetition of the computation in the mobile device, which would waste more energy than if the mobile device had performed the computation in the first place. These are just a few examples of the developing mobile device state prediction techniques' importance.

The current state of mobile devices can be regarded as the consequence of the previous states. Consequently, future behaviour can be predicted based on how a user has been using his/her device. The generation of predictive models of human behaviour has emerged as a topic of interest in several areas, such as recommendation systems, context-aware services, and personalised and adaptive interfaces. For example, several studies have focused on predicting the probability of users to be at a particular place at a given time. Also, Do and Gatica-Perez (2014) and Liao et al. (2012) aimed at predicting which application the user will use next based on contextual information to reduce the time users spend on searching for a specific application.

Although mobile devices constantly evolve as they provide increasing functionality due to the improvements in processing power, storage capabilities, graphics and connectivity; battery capacities do not experience the same growth (Ravi et al., 2008). Power emerges as a critical resource for battery-powered systems as mobile devices. Hence, battery management becomes a crucial requirement to users. Providing battery management information requires the ability to accurately predict remaining battery life in a dynamically changing system. Interestingly, most of the studies in the literature focus on offering location prediction, or application personalisation, instead of analysing the impact of user behaviour in battery level and life. In this context, this work evaluates the suitability of Recurrent Neural Networks (RNN) for predicting future battery levels of mobile devices based on the users' usage pattern of different features, such as the WiFi connection or screen status, among others.

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