Computer Networks 76 (2015) 207–226

Contents lists available at ScienceDirect

Computer Networks

journal homepage: www.elsevier.com/locate/comnet

A preferential attachment model for primate social networks

Mustafa İlhan Akbaş [a,*], Matthias R. Brust [b], Damla Turgut [a], Carlos H.C. Ribeiro [c]

[a] Department of Electrical Engineering and Computer Science, University of Central Florida, Orlando, FL, United States
[b] College of Engineering and Science, Louisiana Tech University, Ruston, LA, United States
[c] Computer Science Division, Technological Institute of Aeronautics, Brazil

ARTICLE INFO

Article history:
Received 11 October 2013
Received in revised form 30 October 2014
Accepted 11 November 2014
Available online 18 November 2014

Keywords:
Wireless sensor networks
Social networks
Mobility
Animal monitoring
Preferential attachment

ABSTRACT

Wildlife monitoring is an enormous organizational challenge due to the required time and effort for setting and maintaining it. It is particularly difficult when the observed species has a complex social hierarchy and different roles for the members in the social group.

In this paper, we introduce an approach to model a primate social network. The primates have complex social behaviors and network structure. As a result, there is a need for realistic computational models to fully understand and analyze the social behavior of such animal groups. We propose a novel spatial cut-off preferential attachment model with a center of mass concept to model the characteristics of the primate groups and a role determination algorithm, which groups the primates into their roles in the society based on the data collected by the wireless sensor and actor networks (WSAN). The performance of the monitoring and role determination algorithms, the applicability of the network formation and the mobility models are evaluated through extensive simulations. The results show that the proposed primate group models deliver networks with properties similar to real-life primate groups in terms of social network characteristics.

© 2014 Elsevier B.V. All rights reserved.

1. Introduction

The characteristics of various animal groups have been analyzed by using collected data from both wildlife and lab experiments [1]. Animal monitoring becomes challenging when the observed species group possess a complex social structure as it requires simultaneous monitoring of multiple individuals and their interactions. For instance, the complex social organization of primate groups requires continuous and long-term monitoring to gather sufficient data [2]. In fact, the social characteristics of primate groups have been investigated in various experiments, but many aspects of their social life remain to be analyzed [3], as real-life and long term movement data is missing for most of the primate groups [1,4]. It is still a challenge for researchers to find out how primate groups would behave and how their social affiliations might change in their natural habitats in the long run. Hence, realistic models of primate networks are critical to analyze their behaviors and to run experiments.

In this paper, we propose an approach to model the social life of primate groups. The initial formation of the animal network and the movement of the animal group must be modeled according to real-life observations and must reflect the social structure of the group. Consequently, it is crucial to use a suitable mobility model derived from the expected and observed mobility patterns. We propose a novel spatial cut-off preferential attachment model and a center of mass concept for modeling the social network connections and the movement models of the group. We use wireless sensor and actor network (WSAN) [5] technology to collect data from the primate network. WSANs have not been used for monitoring primates in

* Corresponding author.
E-mail addresses: miakbas@eecs.ucf.edu (M. İlhan Akbaş), mbrust@latech.edu (M.R. Brust), turgut@eecs.ucf.edu (D. Turgut), carlos@ita.br (C.H.C. Ribeiro).

http://dx.doi.org/10.1016/j.comnet.2014.11.009
1389-1286/© 2014 Elsevier B.V. All rights reserved.

the past. However recent improvements in size, weight, energy consumption and sensing capabilities of sensor nodes as well as their self-organizing aspects make WSANs suitable for wildlife monitoring [6,7]. WSANs can overcome the issues of conventional approaches for wildlife monitoring, which require technically sophisticated processes [8]. For instance, most of the current monitoring methods are highly invasive on the environment and animals under study, which is highly challenging, in particular when periodical resampling is needed. We present a monitoring system model, where primates and their environment are equipped with wireless sensor and actor nodes for continuous data collection. The system aims to collect data from a primate group by building a WSAN among the members of the group and stationary nodes in the environment. The sensor nodes observe events and a limited number of more powerful actor nodes process this information and react accordingly.

The contributions of this work are twofold. We approach the challenge of primate group movement modeling from a social network perspective, adapting the concept of preferential attachment to introduce two network formation and mobility models for primate groups. However, there is no limitation in the node degree of existing preferential attachment social network models, which violates the naturally known attachment limitations for different members in a social primate group. Thus, the first contribution is using a cut-off preferential attachment scheme based on the spatial relationship among the nodes and integrated with the Lévy walk mobility model [9], thus defining a computational model for the foraging of primate groups. The second contribution is the role determination algorithm, which uses the collection of the spatial–temporal relationships to automatically and locally decide on the role of each animal in the society. The social network characteristics of the primate groups created by the model are verified by comparisons with the analyses conducted on real-life primate networks. We modeled the monitoring system composed of wireless sensor and actor nodes in the OPNET modeler with a modular design.

The remainder of this paper is organized as follows. The related work is presented in Section 2. The detailed descriptions of network formation and group mobility are provided in Section 3, and the data collection method and role determination algorithm are presented in Section 4. We discuss the simulation results in Section 5 and conclude in Section 6.

2. Related work

2.1. Group mobility

The models for the generation of movement patterns are essential for the analysis of animal behavior. Hence, the insufficiency of public domain real-life data motivates the development of mobility models. In this section, we present the most current literature on group mobility models and the *"preferential attachment"* method in particular, since we use it in our mobility model.

For the simulation of animal groups and swarms, a variety of mobility models have been proposed. The Reference Point Group Mobility (RPGM) by Hong et al. [10] describes mobility coherence in the movement of a mobile host, i.e. hosts at different positions head towards the same target (or reference point). In RPGM, each group has a logical center, which is not the geographical one, but that defines the entire group's movement behavior similarly to our approach based on the center of mass concept. The node deployment in RPGM is usually random uniform and the nodes have their own random movement in addition to the group motion. In the Virtual Track model (VT model) by Zhou et al. [11], nodes follow *switch stations* deployed in the map, creating virtual tracks. Group nodes are distributed along the virtual tracks while the individual nodes are deployed in the whole area. The switch stations have features allowing the nodes to split into several groups after leaving the switch station. These aspects can be often found in the mobility of animal groups such as birds or primate groups, which split when a new leader founds a new troop. Musolesi et al. [12] approach the problem of the absence of realistic data to model movement patterns from a social perspective. Their model groups collection of nodes together based on social relationships among the individuals. The groups are mapped to a topographical space, including the strength of social ties, and a node belonging to a group moves inside the corresponding group area towards a goal using the Random Waypoint model [13]. In contrast, in our approach we use the Lévy walk model, which has been proposed as an adequate mobility model in most of the animal foraging patterns, such as spider monkeys [14]. Groups in the model of Musolesi et al. [12] also move towards randomly chosen goals with random speeds. As in the model of Hong et al. [10], Musolesi et al. [12] permits changes in the group affiliation based on sociability factor parameter. In our previous work, we also studied the problem of the absence of realistic data for group mobility from a social network perspective [15].

The network formation and mobility models introduced in this paper use the preferential attachment concept, which was implemented by Borrel et al. [16] for designing the mobility model called Pragma. Preferential attachment was introduced by Barabási and Albert [17] to explain a common property of many large networks, according to which the vertex connectivities follow a scale-free power-law distribution. Pragma assumes preferential attachment to centers of interest, considering that individuals move towards attractors, which appear and disappear. Thus, the model describes independent nodes that exhibit a collective behavior. Pragma achieves a scale-free spatial distribution in population growth.

2.2. Social network analysis for primates

Traditional primate relationship analyses focus on dyadic associations. However, all of the primate members and their interactions as a hierarchical group must be taken into consideration for a proper understanding of social structures in a primate society [3]. Therefore, we focus on the hierarchical structure of the primate group and the role of each primate in this hierarchy. Some traditional

Download English Version:

https://daneshyari.com/en/article/452865

Download Persian Version:

https://daneshyari.com/article/452865

Daneshyari.com