The construction of dominance order: comparing performance of five methods using an individual-based model

C.K. Hemelrijk\(^{1,2,3}\), J. Wantia\(^2\) & L. Gygax\(^{2,4}\)

(\(^1\) Theoretical Biology, Centre for Ecological and Evolutionary Studies, Biological Centre, University of Groningen, Kerklaan 30, 9751 NN Haren, the Netherlands; \(^2\) Department of Informatics, University of Zurich, Andreasstrasse 15, 8050 Zurich, Switzerland)

(Accepted: 28 June 2005)

Summary

In studies of animal behaviour investigators correlate dominance with all kinds of behavioural variables, such as reproductive success and foraging success. Many methods are used to produce a dominance hierarchy from a matrix reflecting the frequency of winning dominance interactions. These different methods produce different hierarchies. However, it is difficult to decide which ranking method is best. In this paper, we offer a new procedure for this decision: we use an individual-based model, called DomWorld, as a test-environment. We choose this model, because it provides access to both the internal dominance values of artificial agents (which reflects their fighting power) and the matrix of winning and losing among them and, in addition, because its behavioural rules are biologically inspired and its group-level patterns resemble those of real primates. We compare statistically the dominance hierarchy based on the internal dominance values of the artificial agents with the dominance hierarchy produced by ranking individuals by (a) their total frequency of winning, (b) their average dominance index, (c) a refined dominance index, the David’s score, (d) the number of subordinates each individual has and (e) a ranking method based on maximizing the linear order of the hierarchy. Because dominance hierarchies may differ depending on group size, type of society, and the interval of study, we compare these ranking methods for these conditions. We study complete samples as well as samples randomly chosen to resemble the limitations of observing real animals. It appears that two methods of medium complexity (the average dominance index and David’s score) lead to hierarchical orders that come closest to the hierarchy based on internal dominance values of the agents. We advocate usage of the average dominance index, because of its computational simplicity.

\(^3\) Corresponding author’s e-mail address: c.k.hemelrijk@rug.nl
\(^4\) Present address: Centre for proper housing of ruminants and pigs, Swiss Federal Veterinary Office, Agroscope FAT Taenikon, 8356 Ettenhausen, Switzerland

© Koninklijke Brill NV, Leiden, 2005

Behaviour 142, 1037-1058

Also available online -
Introduction

Dominance hierarchy is a central theme in the study of animal behaviour. It is correlated with many behavioural variables, such as social activities, success at foraging and reproduction. The dominance hierarchy is thus a central feature in many studies of animal behaviour. Yet, in observing animal behaviour, several hierarchical orderings of individuals are usually possible and it is unclear which is the more realistic one. Whereas much has been written on the question how to measure dominance rank, no unanimous conclusion as to what method should be preferred has been reached. It is difficult to decide this, because we have no independent information about real internal power or dominance values, that influence the winning tendencies; besides, winning tendencies change in time and depend on the social situation (Chase et al., 2003). In the present paper, we compare statistically the efficiency of several ranking methods in a model consisting of artificial agents that group and compete. This method is efficient, since here we have unique access both to the internal power or dominance values of the agents (that represent their winning tendencies) and to the frequency of their victories and defeats in a model that shows large resemblances to behaviour of real animals (Hemelrijk, 1999).

The evaluation method we use is new, because we determine the degree with which the outcome of a ranking method matches the real dominance hierarchy among agents based on their internal dominance values or power. We test the agreement of the internal ‘true’ dominance values and the dominance values calculated according to the different methods. The model, called DomWorld, is based on self-organisation that arises from the effects of self-reinforcement and spatial structure (Hemelrijk, 1999, 2000, 2002). Here, agents merely group and perform competitive interactions in which the effects of winning and losing are self-reinforcing (winning/losing an interaction increases the chance of doing so again). These self-reinforcing effects have been observed in many animal species, ranging from invertebrates such as insects (Theraulaz et al., 1992), crustaceans (Karavanich & Atema, 1998) via fish (Hsu & Wolf, 1999) and birds (Drummond & Canales, 1998) to mammals, such as deer (Thouless & Guinness, 1986), primates (Barchas...