Effects of Local Communication and Spatial Position in a Collective Decision-Making Model

Brent E. Eskridge¹ and Ingo Schlupp²

¹Southern Nazarene University, Bethany, OK, USA ²University of Oklahoma, Norman, OK, USA beskridge@snu.edu

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Motivation

- Implementing large-scale collaborative behavior in robots
- Fission-fusion dynamics of large aggregations
- Bio-inspired collective decision-making
- Limited by local communication



Introduction	Background	Results	Wrapup
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Spatial Position of Initiator





- Central individuals will be more successful initiators
- Incorporating temperament traits will increase success rate of non-central initiators

Background

Results 00000000 Wrapup 00

Decision-making events

Three decision-making events

- Initiate a movement
- Follow an initiator
 - Cancel a movement





Departed individuals

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Temperament Traits: Overview

- Temperament is a set of repeatable differences in behavior across several traits
 - AKA Personality
- Most commonly student trait is bold/shy
- As many as 14 traits in primate behavior alone [1]
- Some determined by intrinsic state, others by life history





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Temperament Traits: Effects of Position





Mean distance

Mean resultant vector

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Mean Resultant Vector



Small MRV



Large MRV

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Metric vs. Topological Distance Measures





Metric

Topological

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Numerical Implementation

- Group sizes from 20–50 individuals
- 50 spatial distributions
- Success simulations (Hypothesis 1)
 - 2,000 initiations per individual
- Temperament trait simulations (Hypothesis 2)
 - ▶ *N* × 4,000 initiations
 - Group behavior randomly chosen for each initiation
- Both topological and metric distances used
- All individuals must participate for success

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Results: Success Probabilities



Mimicking Neighbors







Vrapup

Metric N = 50



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Results: Success Probability Correlations

Туре	<i>N</i> = 20	<i>N</i> = 30	<i>N</i> = 40	<i>N</i> = 50
Metric	0.916	0.918	0.925	0.924
Topological	0.934	0.942	0.949	0.950

Success vs. mimicking neighbor count

Results oo●ooooo

Results: Success Probabilities

- Number of individuals that consider an individual a nearest neighbor (i.e. mimicking neighbors)
- $\blacktriangleright \ \ More \ mimicking \ neighbors \rightarrow More \ successful$
 - Central individuals as much as 40%
 - Periphery individuals as low as 10%
 - Dependent on distance measure
- Topological distance had more connections for N = 20, 30
- Metric distance had more connections for N = 50

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Results: Temperament Trait for Navigate





Topological Bold

Introduction

Background

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Results: Temperament Trait for Explore





Metric Active

Topological Active

Introduction

Background

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Results: Temperament Traits for Escape





Metric Fearful

Topological Fearful

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Discussion			

Significance of position

- Central individuals were more successful
- Peripheral individuals rarely succeeded at all
- Factors contributing to success
 - Mimicking neighbors
 - Temperament traits help, but can't overcome few mimicking neighbors
- Requirement for all individuals to participate is too restrictive
 - Exploration consists of a few individuals
 - Escaping individuals rarely cancel

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Questions?

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Collective-Decision Making Model

- Modeled after observations of White-faced Capuchin Monkeys [3, 2]
- Confirmed in sheep groups of 2–8 members [4]
- No movement



Calculating Initiation Events

All individuals can initiate movement

au_{i}

(1)

- *\(\tau_i\)* calculated from observation
- Initiation times drawn from: k/τ_i

Calculating Following Events

- Group size —
- Individuals already departed -

 $\tau_r = \frac{1}{k} \left(\alpha_f + \beta_{f} - \frac{1}{k} \right)$

- α_f and β_f calculated from observation
- Following times drawn from: $1/\tau_r$

Calculating Cancelling Events

$$C_r = k \frac{\alpha_c}{1 + (r/\gamma_c)^{\varepsilon_c}}$$

(3)

- Individuals already departed /
- α_c , γ_c and ε_c calculated from observation
- Cancellation times drawn from: C_r

Behavior	Distance	<i>N</i> = 20	<i>N</i> = 30	<i>N</i> = 40	<i>N</i> = 50
Navigate	Metric	0.727	0.700	0.673	0.675
	Topological	0.789	0.750	0.705	0.662
Explore	Metric	0.554	0.593	0.621	0.630
	Topological	0.529	0.486	0.476	0.474
Escape	Metric	0.513	0.518	0.532	0.529
	Topological	0.439	0.396	0.386	0.378

Behavior	Distance	N = 20	<i>N</i> = 30
Navigato	Metric	$\textbf{0.727} \pm \textbf{0.038}$	$\textbf{0.700} \pm \textbf{0.056}$
Inavigate	Topological	$\textbf{0.789} \pm \textbf{0.053}$	0.750 ± 0.052
Explore	Metric	$\textbf{0.554} \pm \textbf{0.087}$	$\textbf{0.593} \pm \textbf{0.078}$
	Topological	$\textbf{0.529} \pm \textbf{0.108}$	$\textbf{0.486} \pm \textbf{0.075}$
Escape	Metric	$\textbf{0.513} \pm \textbf{0.058}$	0.518 ± 0.054
	Topological	$\textbf{0.439} \pm \textbf{0.049}$	$\textbf{0.396} \pm \textbf{0.049}$

Behavior	Distance	N = 40	<i>N</i> = 50
Navigato	Metric	$\textbf{0.673} \pm \textbf{0.068}$	0.675 ± 0.073
Inavigate	Topological	$\textbf{0.705} \pm \textbf{0.058}$	$\textbf{0.662} \pm \textbf{0.059}$
Explore	Metric	0.621 ± 0.057	$\textbf{0.630} \pm \textbf{0.049}$
	Topological	0.476 ± 0.073	0.474 ± 0.068
Escape	Metric	0.532 ± 0.033	$\textbf{0.529} \pm \textbf{0.036}$
	Topological	0.386 ± 0.036	0.378 ± 0.034