Consensus Costs and Conflict in a Collective Movement

Tim Solum[1], Brent E. Eskridge[1], and Ingo Schlupp[2]

[1]Southern Nazarene University, Bethany, OK, USA
[2]University of Oklahoma, Norman, OK, USA

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Collective Movement

- Observed in nature
  - Flocking of birds
  - Shoals of fish
  - Migrating wildebeests
- Benefits in nature
  - Increased foraging success
  - Protection from predators
- Benefits in robot swarms
  - Robustness
  - Flexibility
  - Scalability

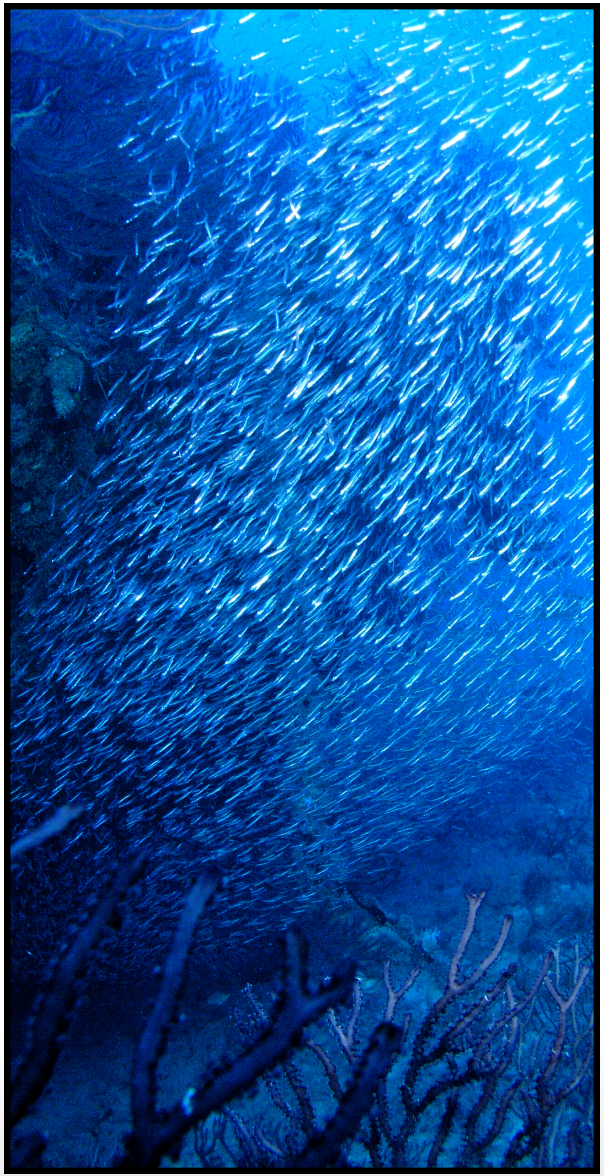
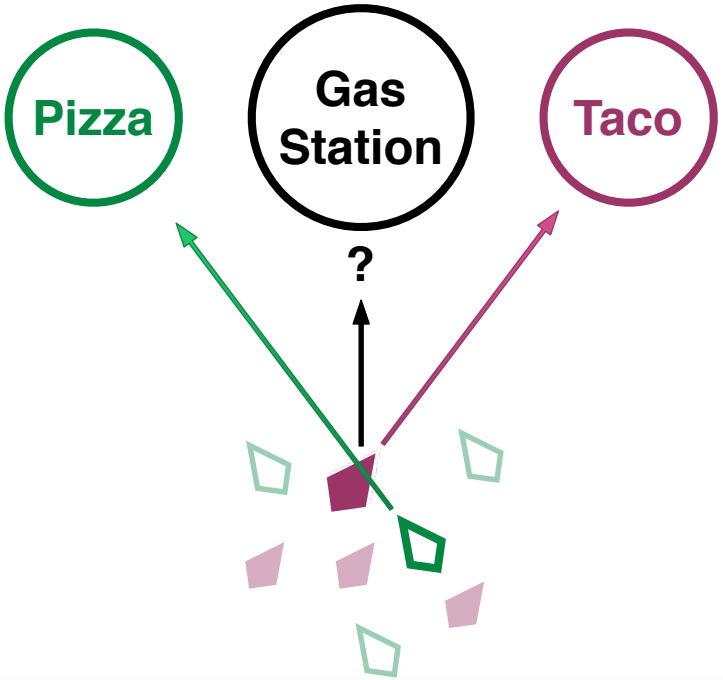


Image available at http://cdni.wired.co.uk/1920x1280/s_v/Shoal4_CNT_18jun12_rex_b.jpg

Costs

- Compromise is not an option [2]
- Individual may not achieve goal
- Getting pizza when wanting tacos



Conflict

- Conflict arises from differing preferences [1]
  - Often ignored in collective movement systems
- Decisions can take longer but
- Could be useful when compromise is not an option

Research Hypothesis

Conflict minimizes consensus costs in collective movements while allowing for group cohesion

Collective Movement Model

- Based on observations of natural systems [4] [3]
  - Capuchin monkeys
  - Validated in sheep
- Modifications
  - Discrete time
  - Movement
    - Multiple Initiators
  - Destination Preferences
  - Conflict

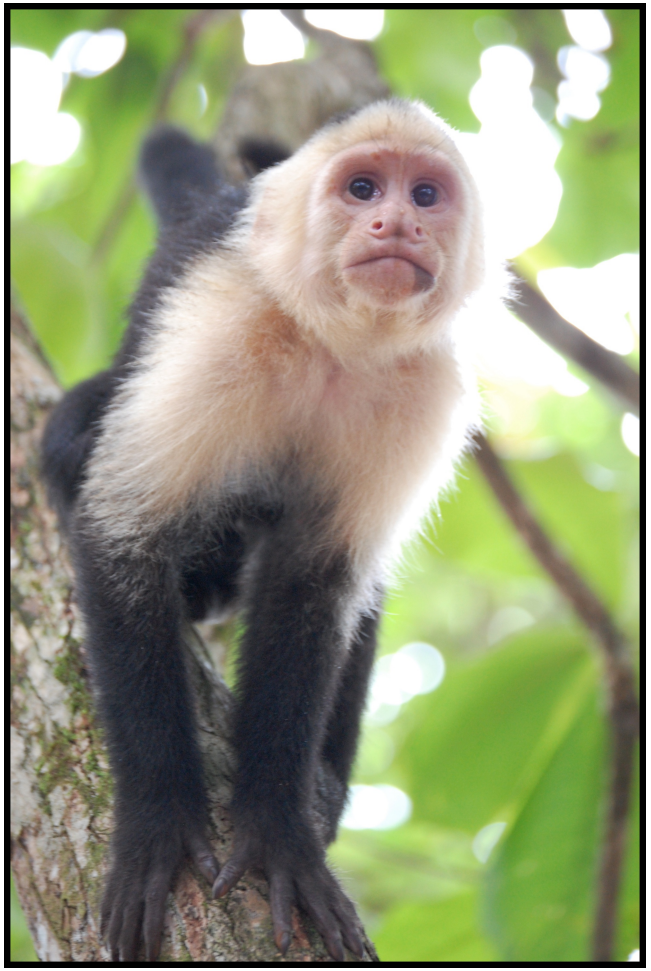
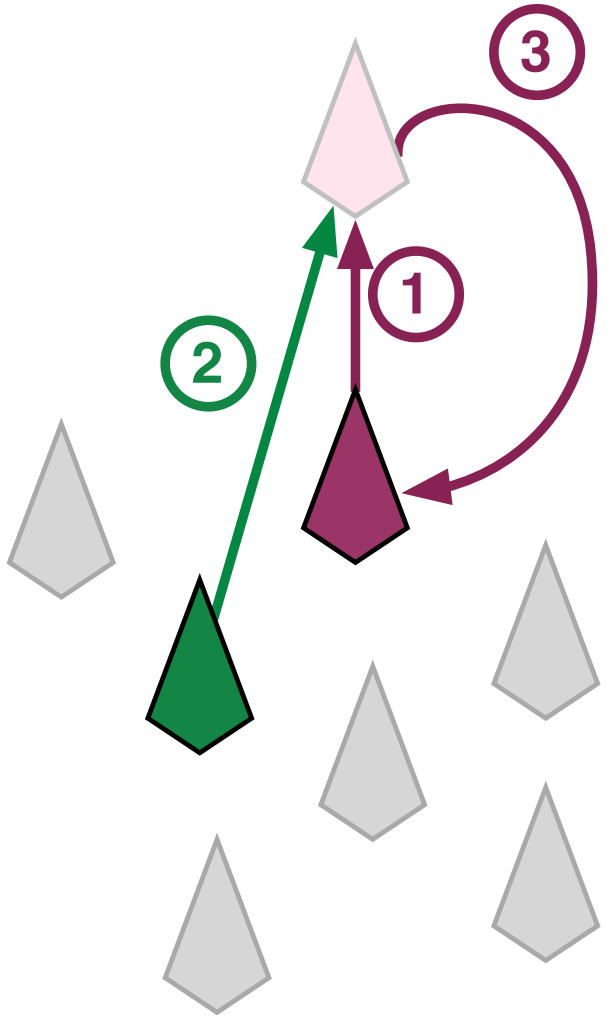


Image available at http://a-z-animals.com/animals/white-faced-capuchin/pictures/1895/

Decision Rules

Three decision-making events

1. Initiate a movement
2. Follow an initiator
3. Cancel a movement



Decision Probabilities

Initiate

$$\tau_i = \frac{1}{\tau_o} \tag{1}$$

Follow

$$\tau_r = \alpha_f + \beta_f \frac{N - r}{r} \tag{2}$$

Cancel

$$C_r = \frac{\alpha_c}{1 + (r/\gamma_c)^{\epsilon_c}} \tag{3}$$

Discrete Time

- **Do Nothing** decision needed
  - Decisions made at every time step
  - Individuals continue doing what they were doing
- Must do something if current leader changes groups

Modified Decision Probabilities

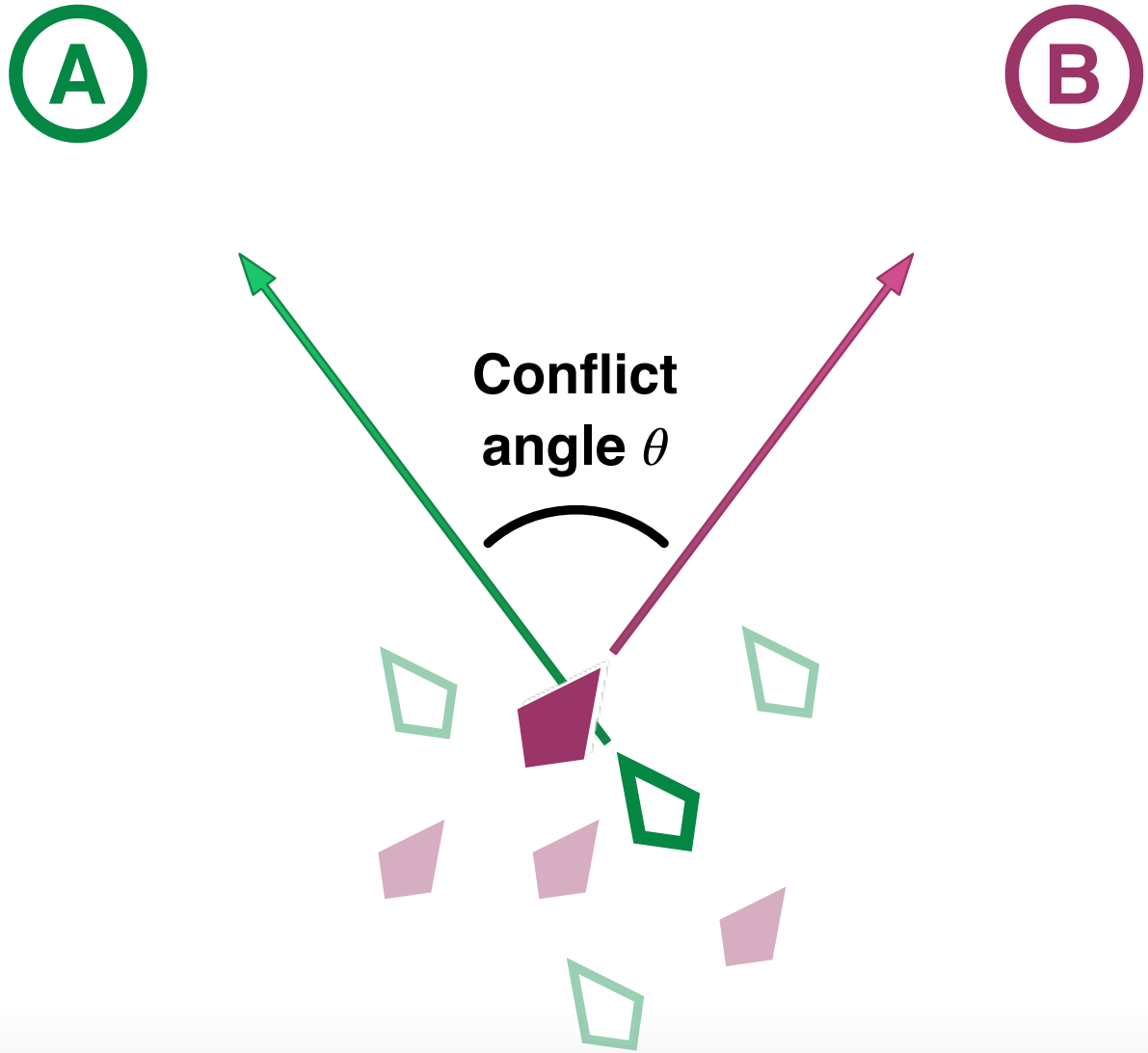
Initiation

$$\tau_i = \frac{k}{\tau_o} \tag{4}$$

Following

$$\tau_r = \frac{1}{k}(\alpha_f + \beta_f \frac{N - r}{r}) \tag{5}$$

Conflict Implementation



Conflict Calculation

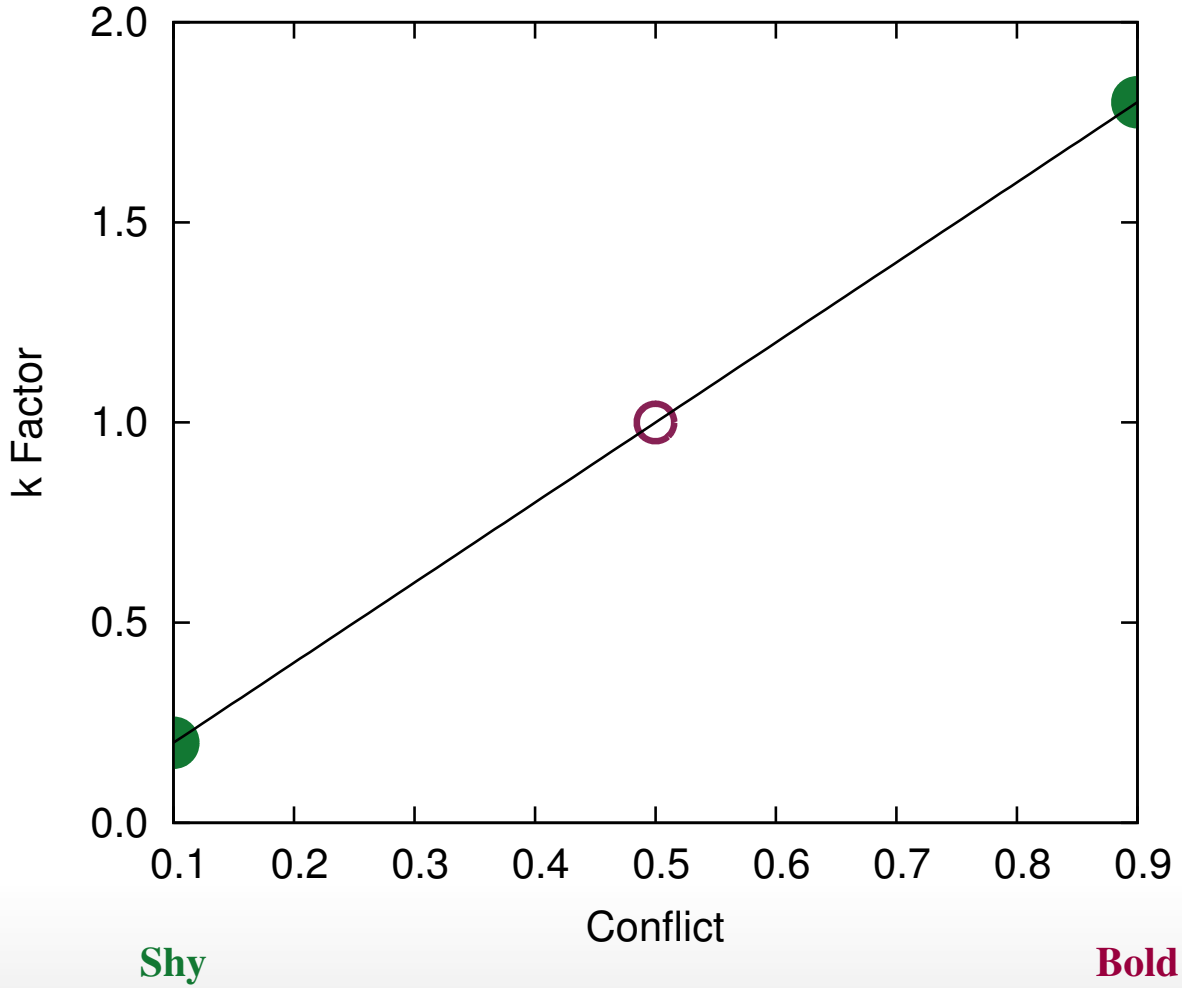
$$C_i = \frac{|\theta|}{\pi} \tag{6}$$

C_i Conflict for individual i

θ Conflict angle $[-\pi{:}\pi]$

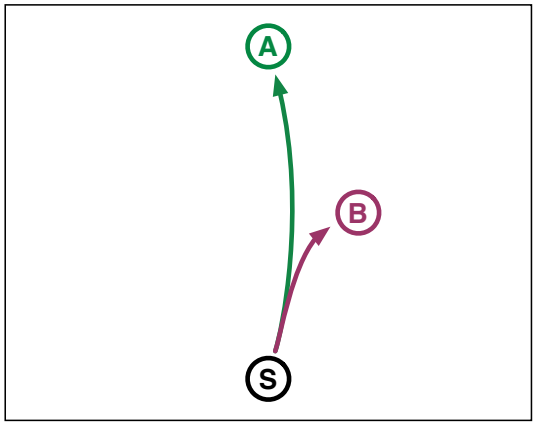
K Factor as Function of Conflict

$$k = 2C_i \tag{7}$$

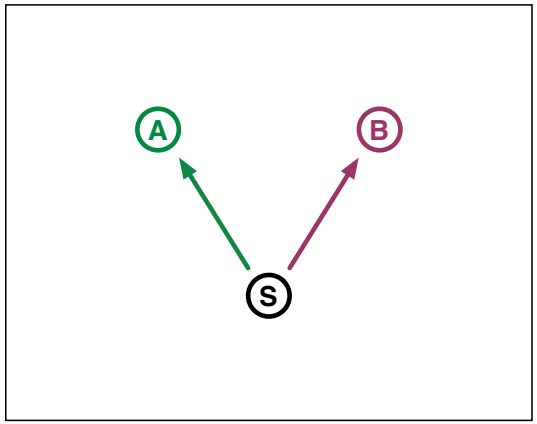


Evaluation Environments

Minimum Initial Conflict



Moderate Initial Conflict



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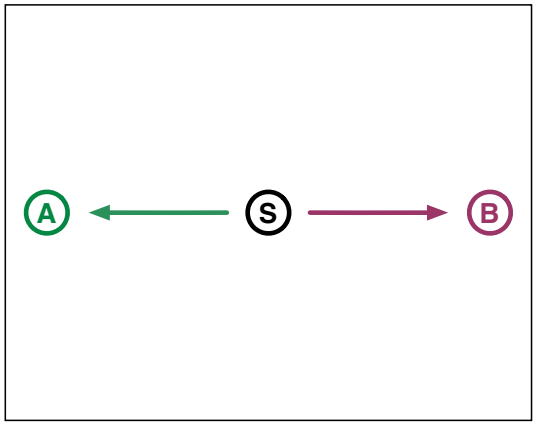
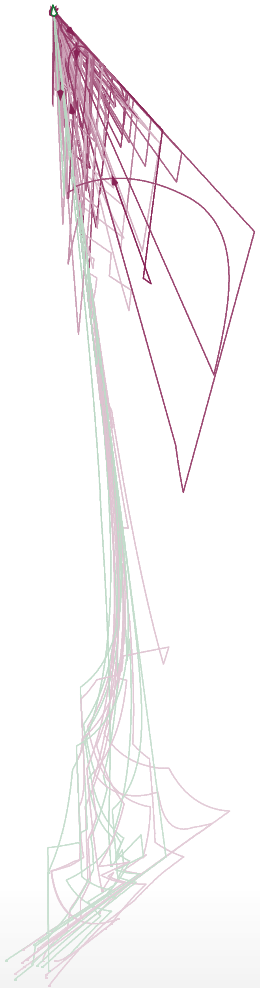


Simulations

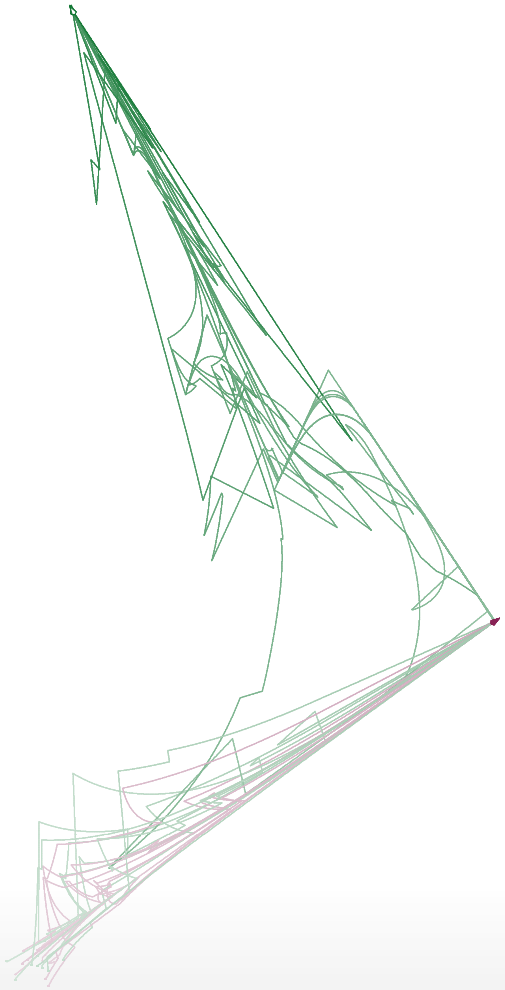
- 3 treatments were used on each environment
  - No conflict and no consensus costs (*Baseline*)
  - No conflict and consensus costs
  - Conflict and consensus costs
- No consensus costs means that the entire group prefers the same destination
- 1,000 simulations per environment
- 20,000 max time steps

Minimum Initial Conflict Movement Histories

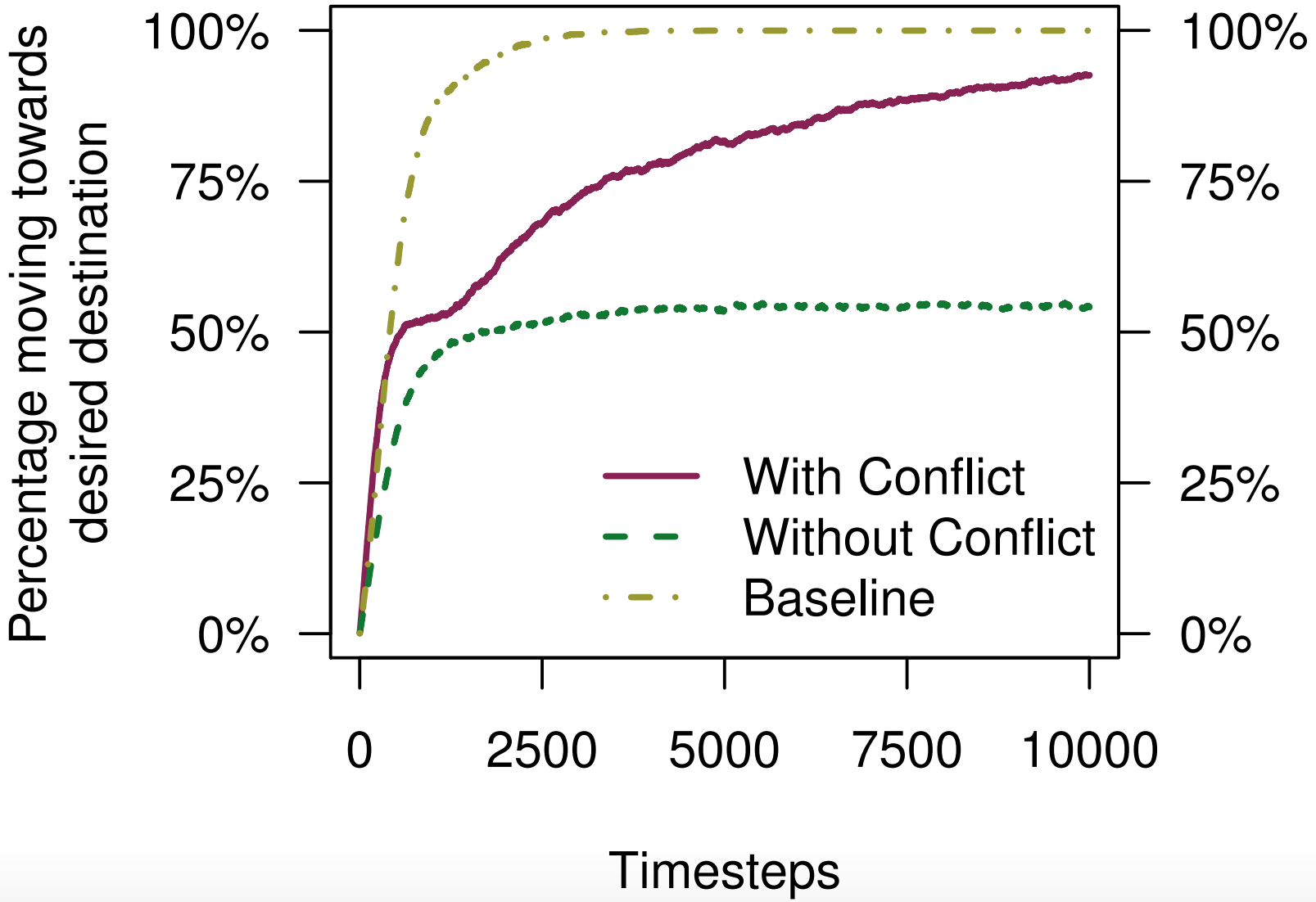
Without Conflict



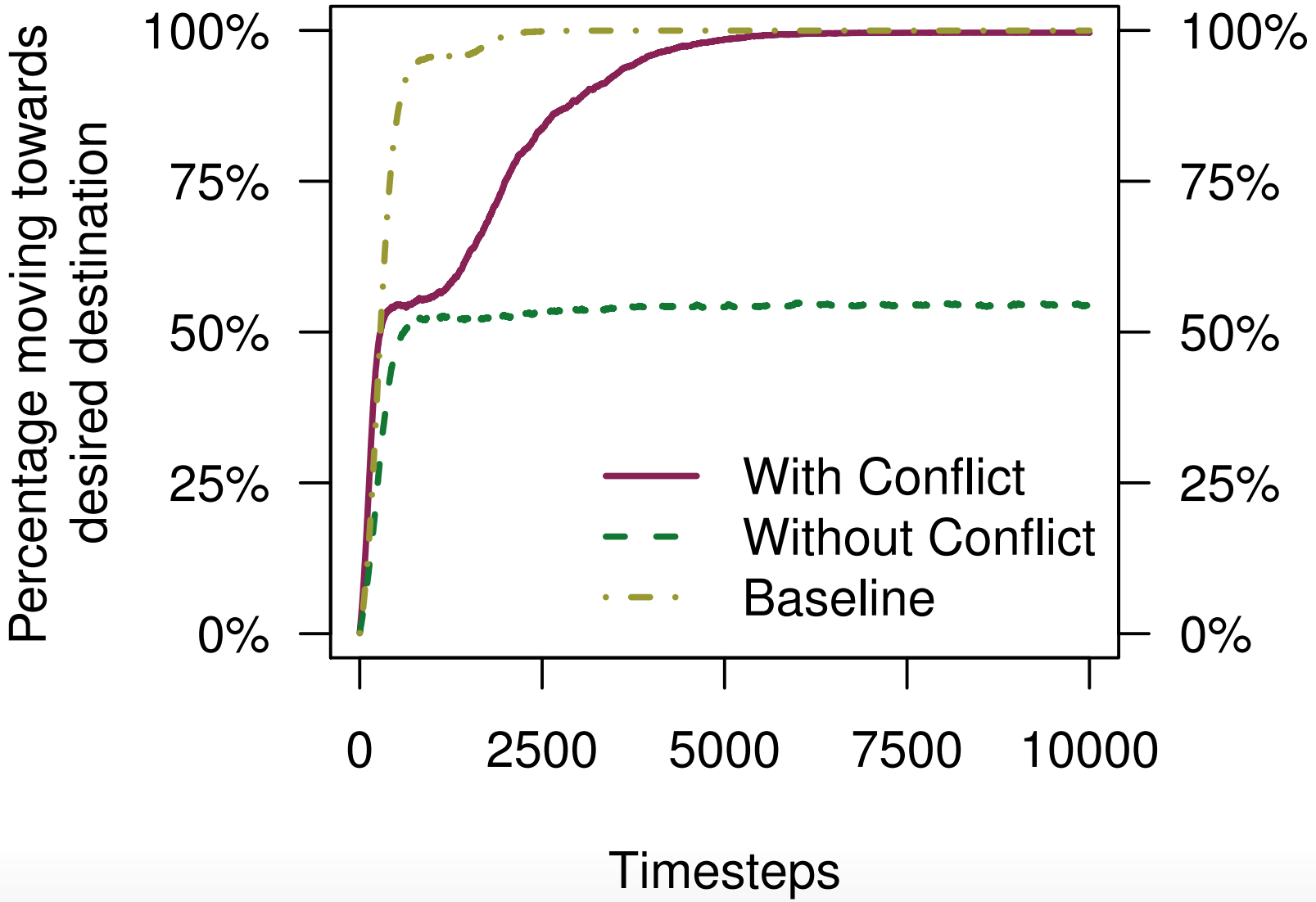
With Conflict



Minimum Initial Conflict with 10 Individuals



Minimum Initial Conflict with 50 Individuals



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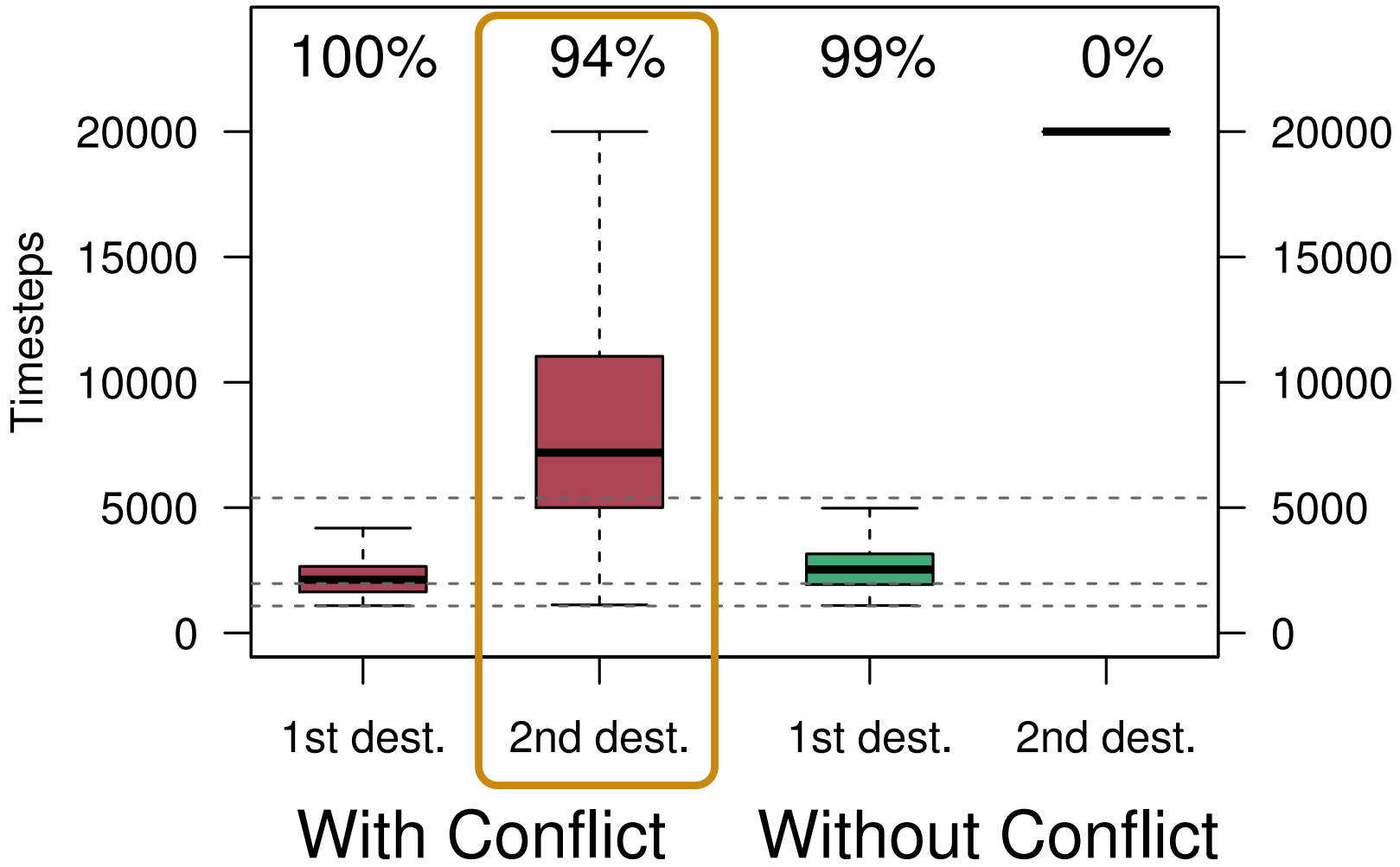

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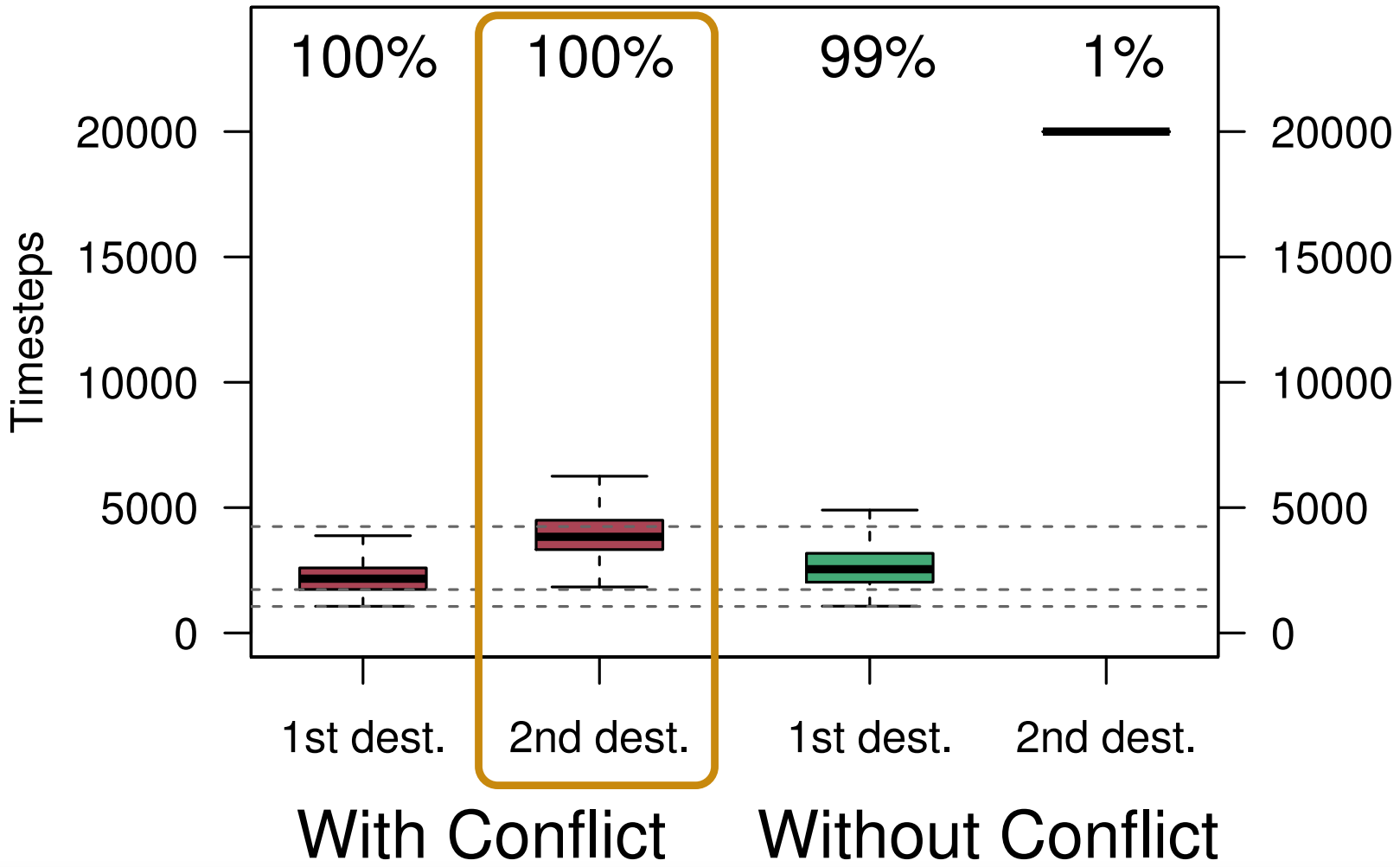

Conclusions

- Addition of conflict
  - Balanced consensus costs with individual preferences
  - Significantly improved individual success
- Consensus costs cause individuals to not achieve their goals
  - Up to 50% in our simulations
- If we don't want to pay consensus costs, conflict successfully reduces them

Future Work

- Can we balance consensus costs and individual preferences?
- Multi-objective Optimization
- Use a more tunable decision-making model [5]
- Add predation and uninformed agents
- Improve movement (e.g., Flocking)

Acknowledgments

- Blake Jordan
- Southern Nazarene University
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Questions?

Videos and other materials can be found at:

www.csne.snu.edu/tag/gecco2014/

Source code can be found at:

github.com/snucsne/bio-inspired-leadership

References

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Supplemental

Initiation Probability

$$\tau_i = \frac{1}{\tau_o} \tag{8}$$

τ_i - initation rate
τ_o - initiation rate constant
Assumes all agents within a group are identical

Following Probability

$$\tau_r = \alpha_f + \beta_f \frac{N - r}{r} \tag{9}$$

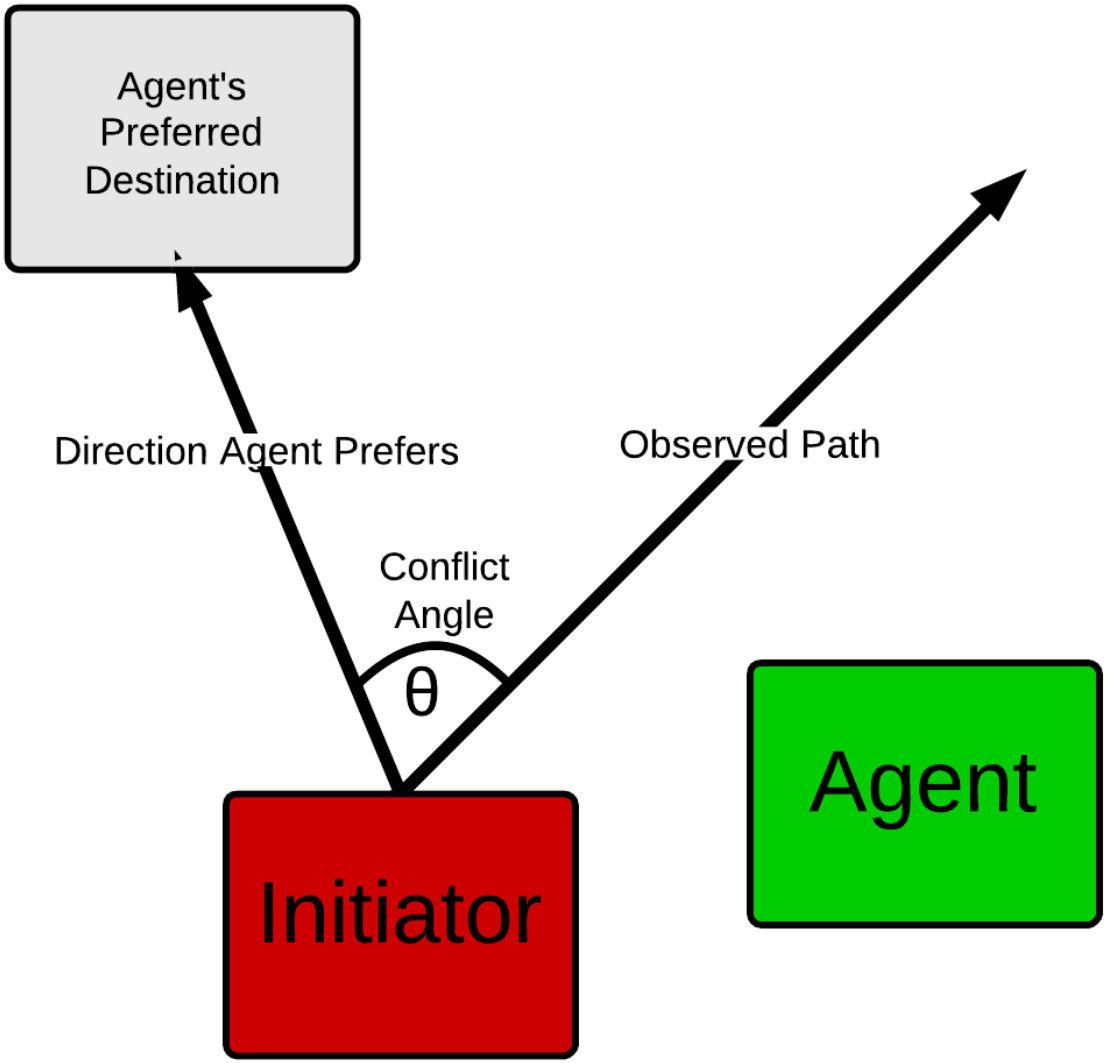
τ_r - follow rate
α_f and β_f - constants
N - number in the group
r - number following initiator

Cancellation Probability

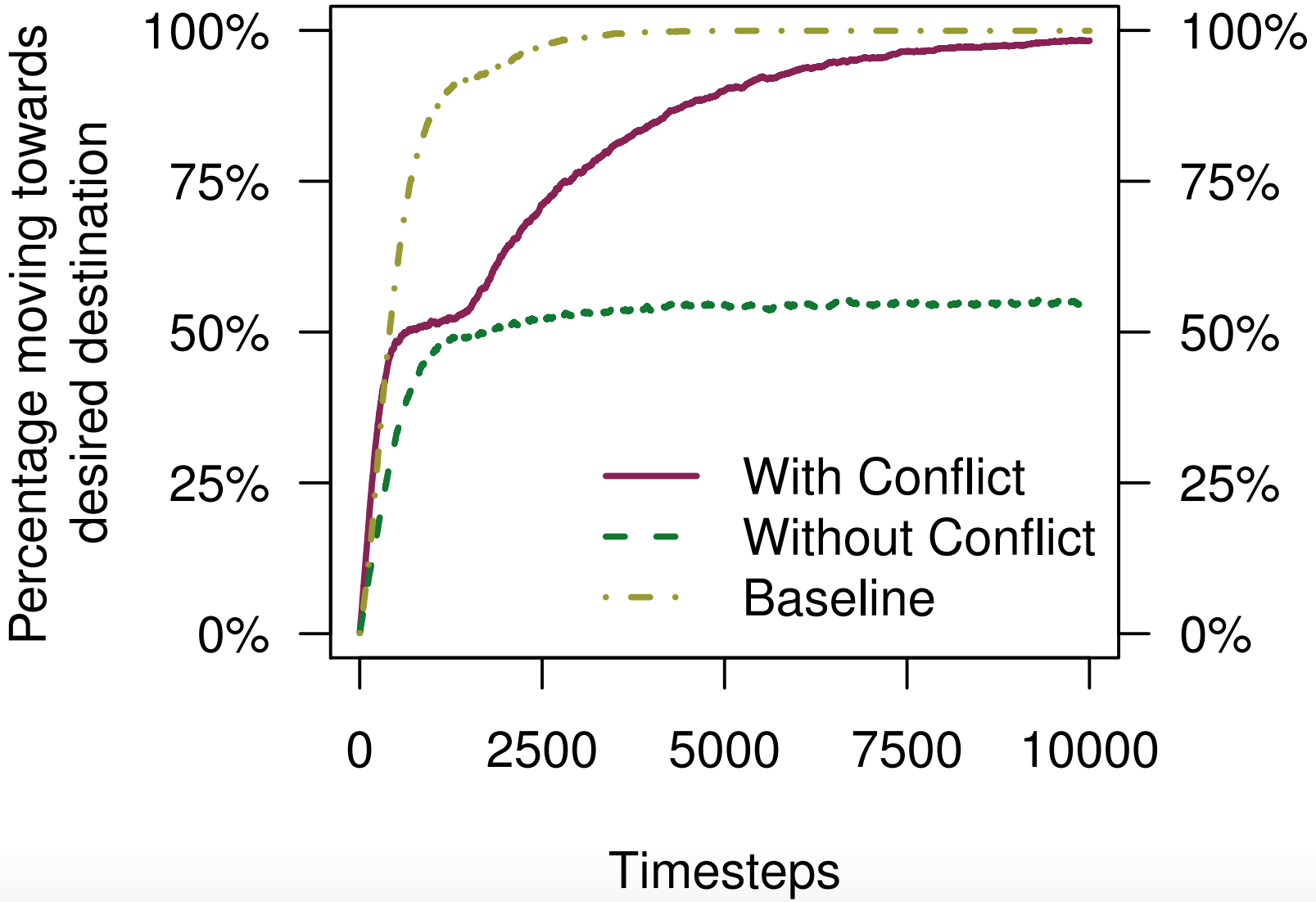
$$C_r = \frac{\alpha_c}{1 + (r/\gamma_c)^{\epsilon_c}} \tag{10}$$

C_r - cancel rate
α_c,λ_c and ϵ_c - constants
r - number following initiator

Conflict


Agent's
Preferred
Destination
Direction Agent Prefers
Observed Path
Conflict
Angle
θ
Initiator
Agent

Moderate Initial Conflict with 10 Individuals



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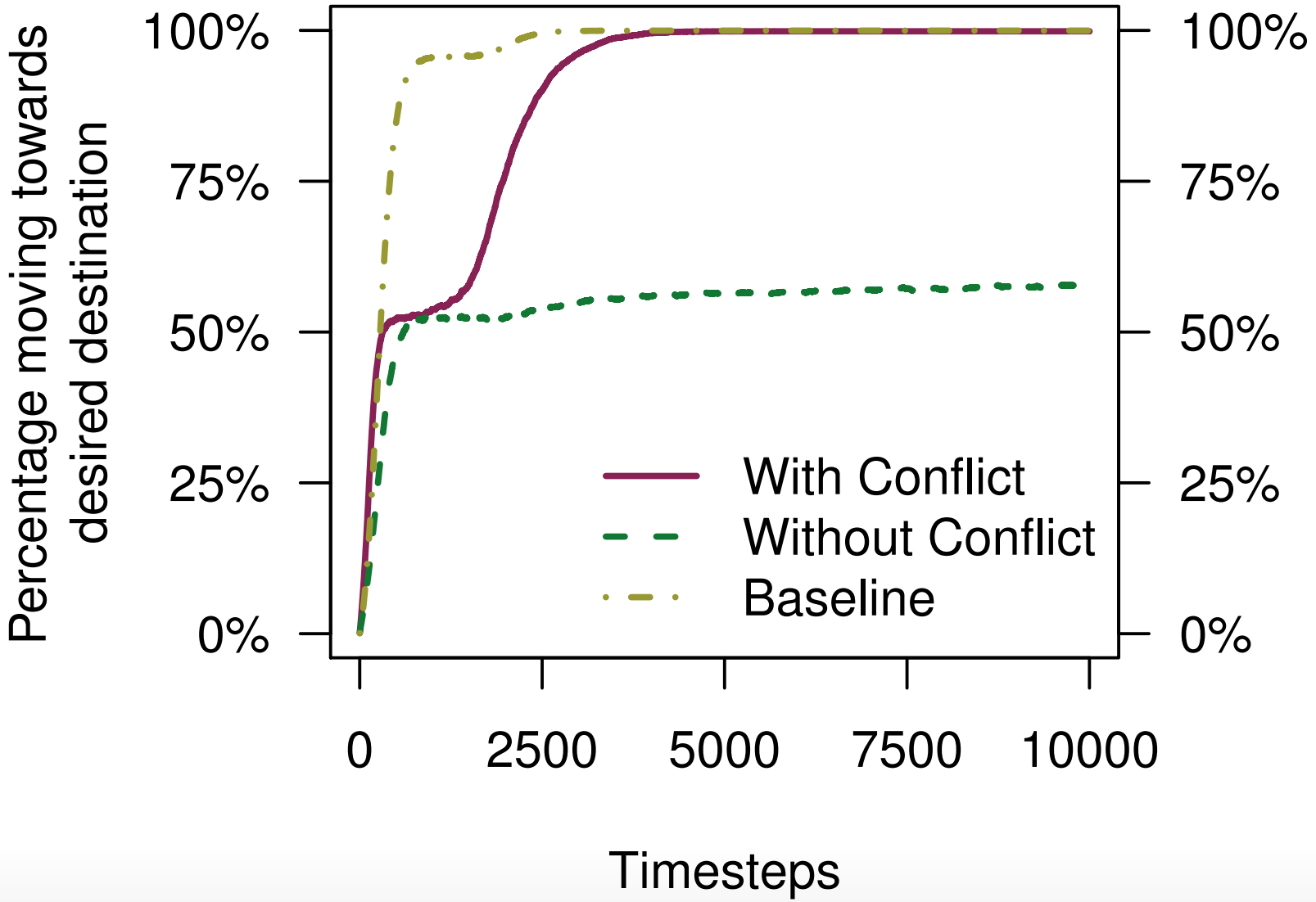

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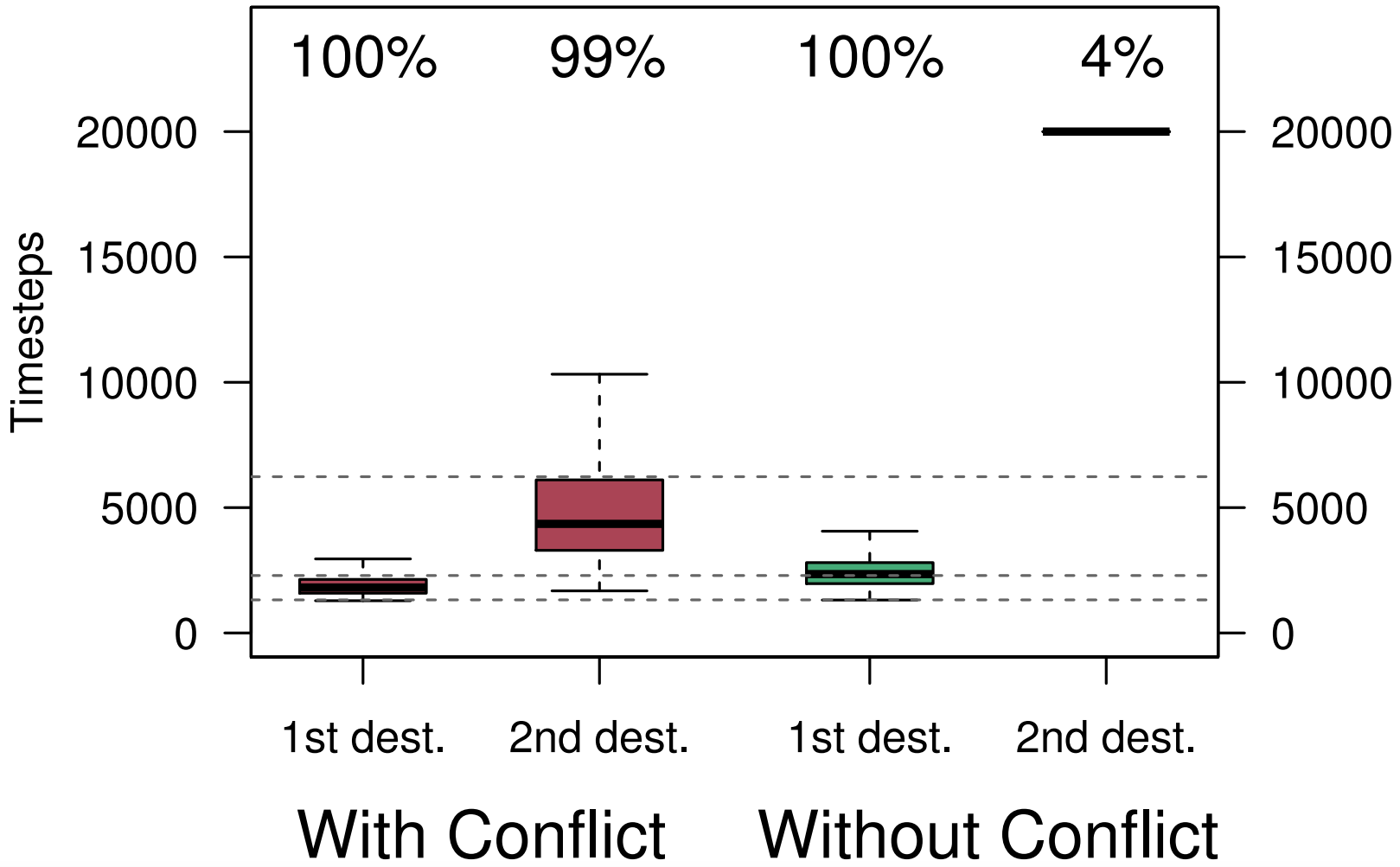

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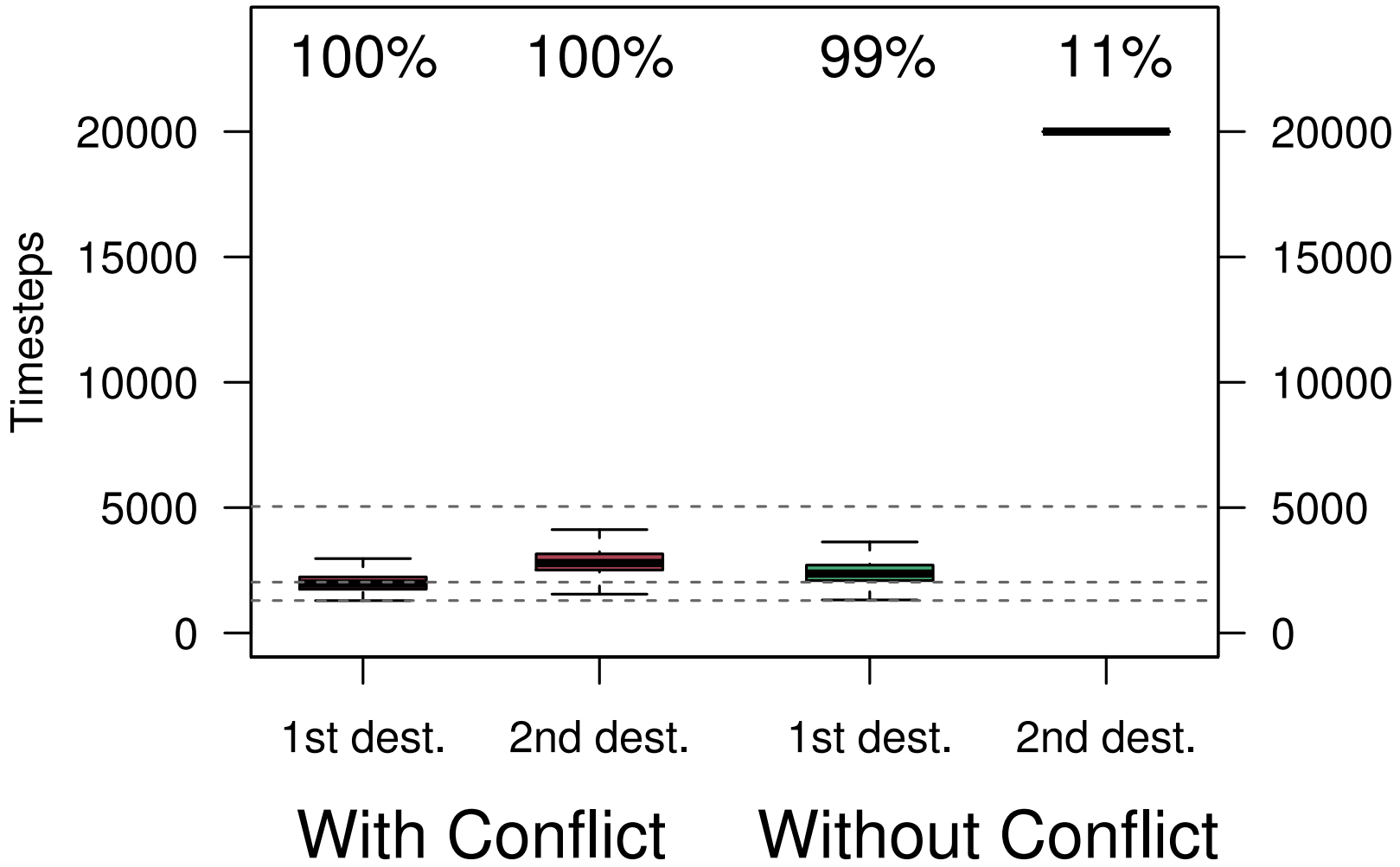

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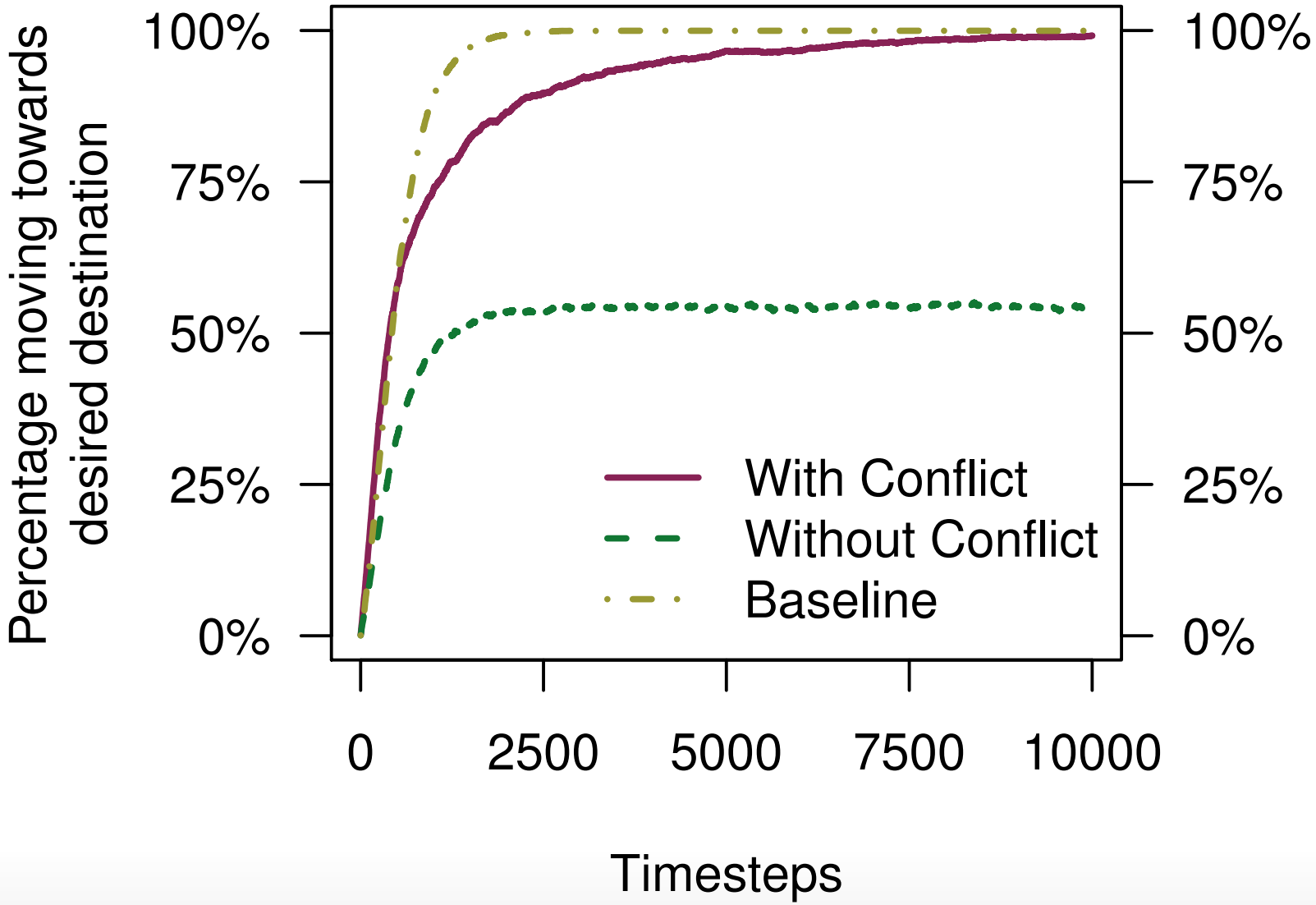

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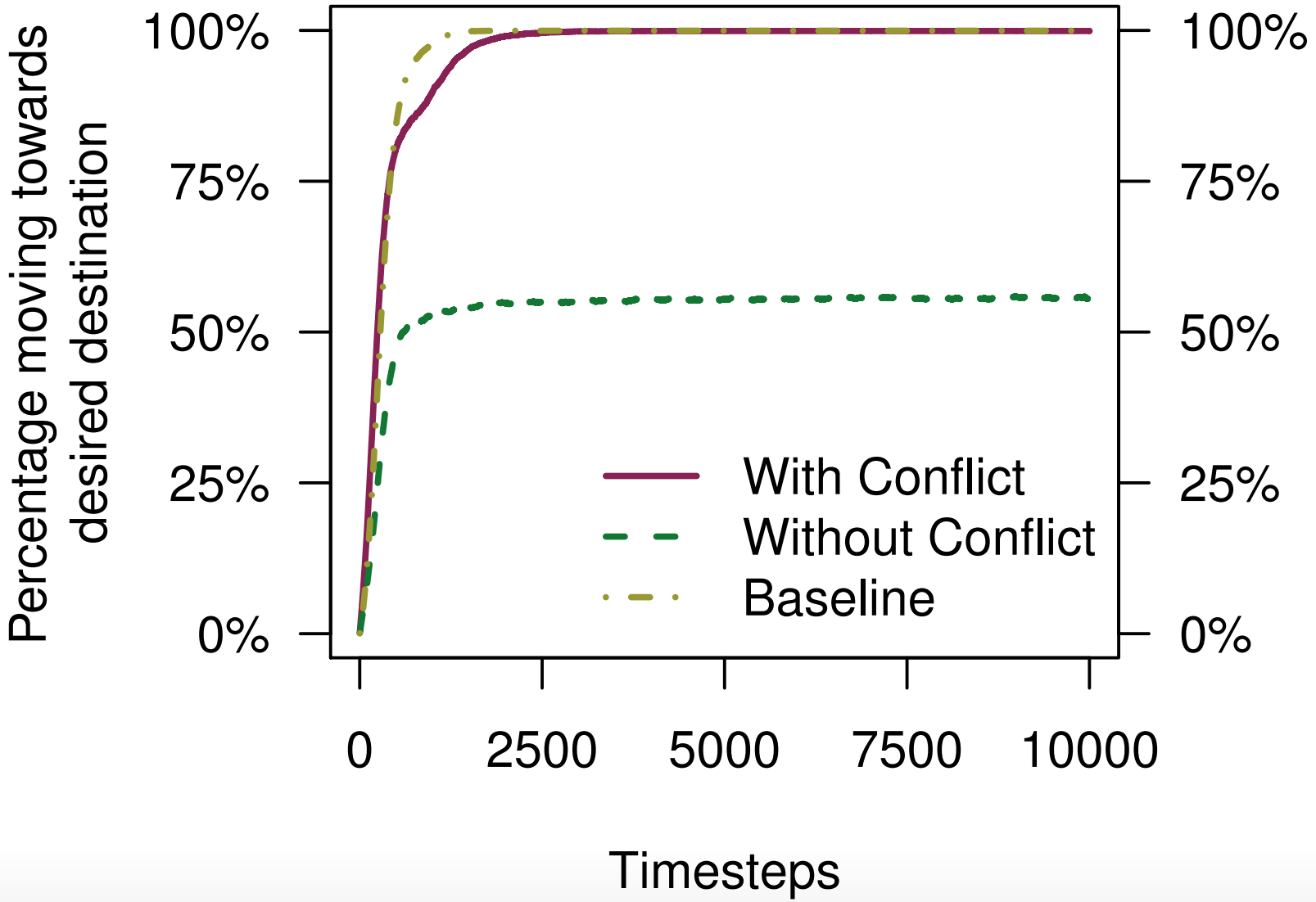

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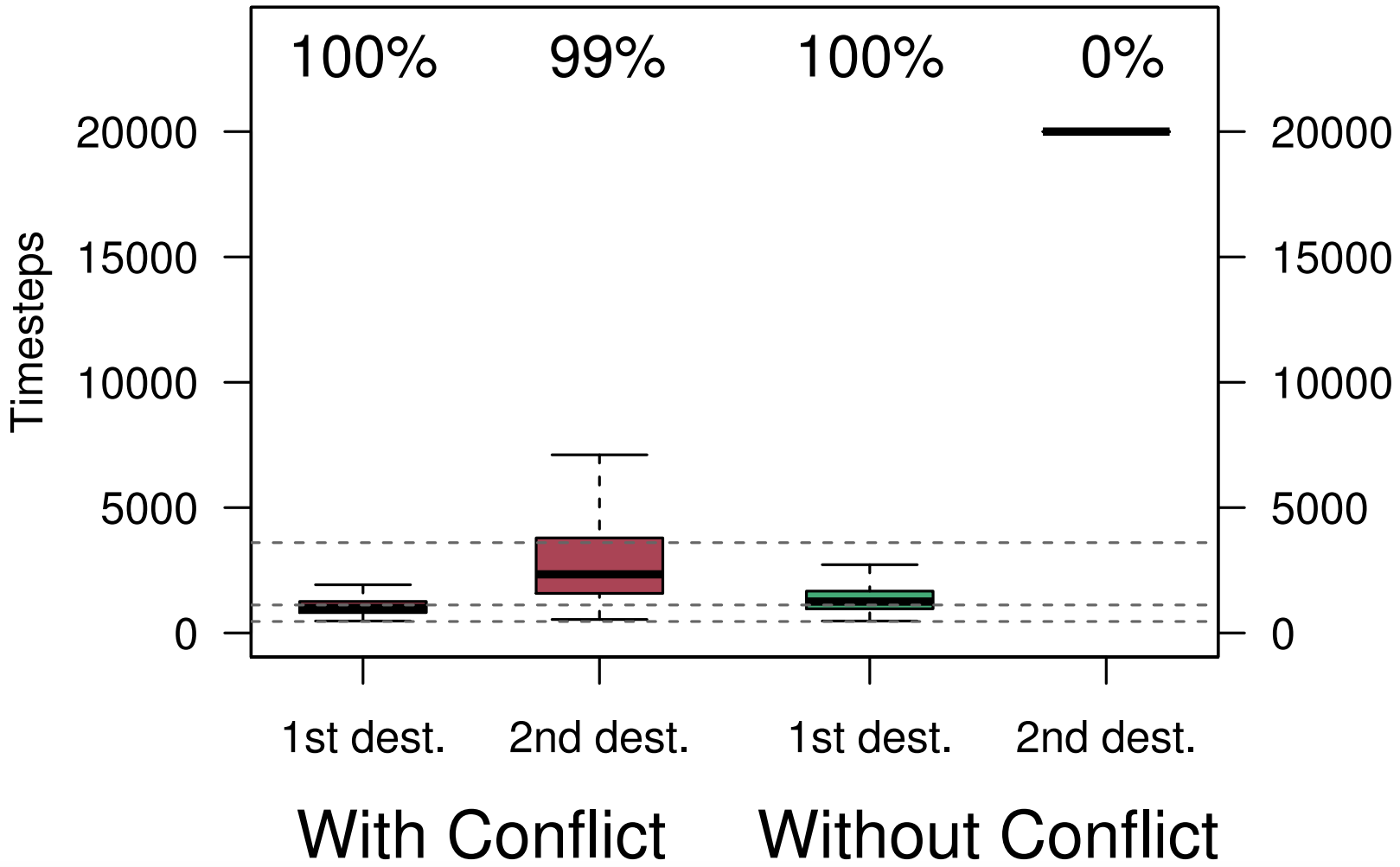

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