Framework for Inferring Leadership Dynamics of Complex Movement from Time Series

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Get to know leadership

Definition

- Process: Leaders influence the group to achieve collective goals

Types of leaders

- Leaders by title (CEO etc.)
- **Emerging leaders (by behaviors)**

Fields of study

- Managing leadership (human)
- **Leadership inference from data**

Emerging leadership types:

- Explicit leadership (leaders influence a group)
- Implicit leadership (leaders unknown to a group)

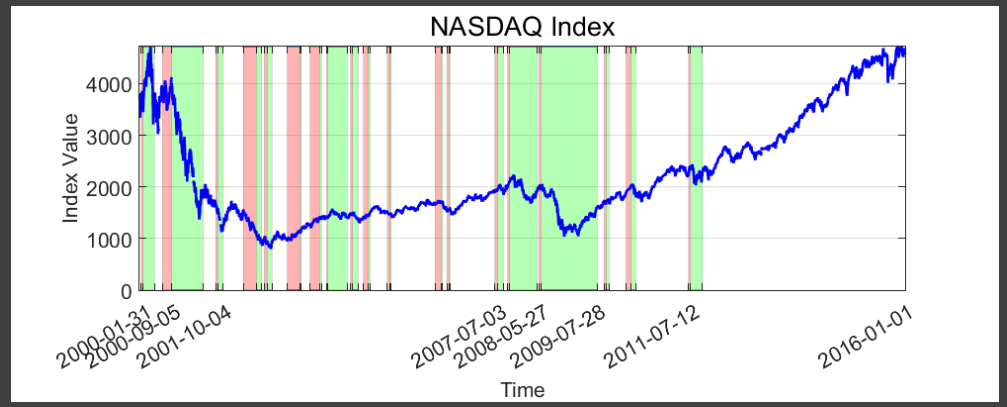
Leadership of coordination

Definitions

- Coordination: collective behaviors (patterns)
- Leaders: Individuals initiate collective patterns that everyone follows

Why we study leadership?: Leadership plays a key role in

- Group Decision Making Process (human and social animals)
- Collective events (e.g. Stock market)



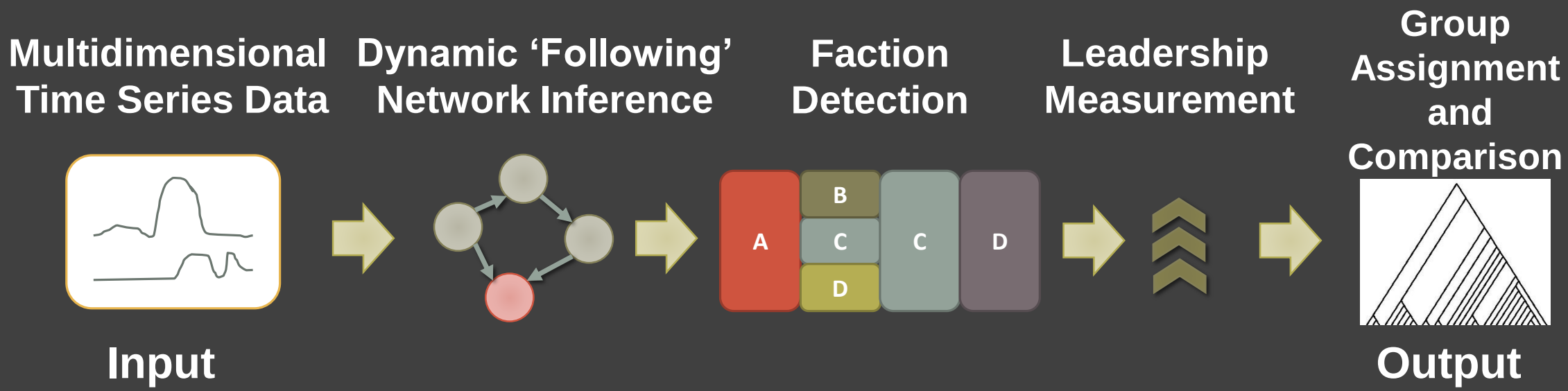
Tracking positions by GPS devices

Challenges

- Who are leaders and how can we infer them?
- How can we infer multiple coordinated activities that can happen concurrently?
- How can we infer merging and splitting events of movement

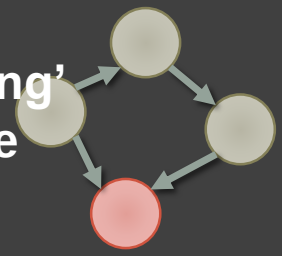
Method

High-level mFLICA* framework procedure

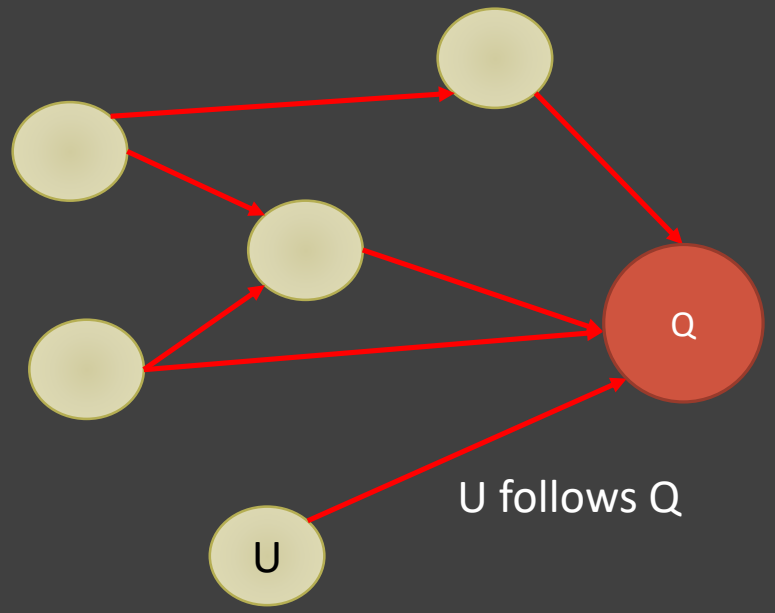


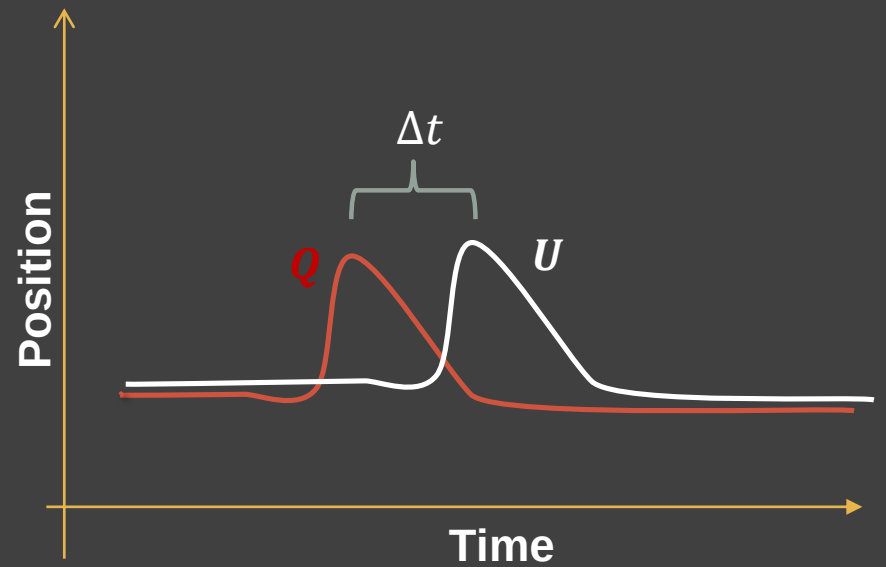
*The Framework of Multiple-Faction Leadership Inference in Coordinated Activity

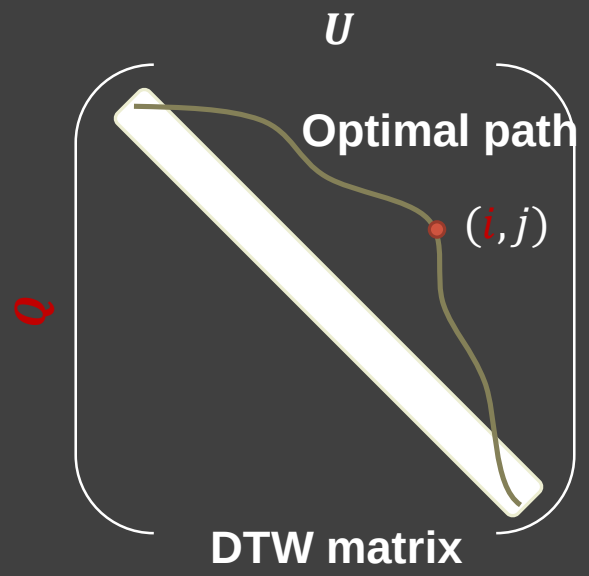
Dynamic 'Following' Network Inference



Following Network





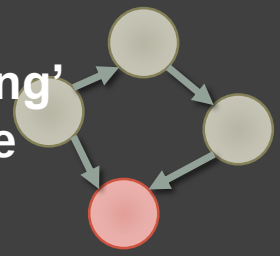


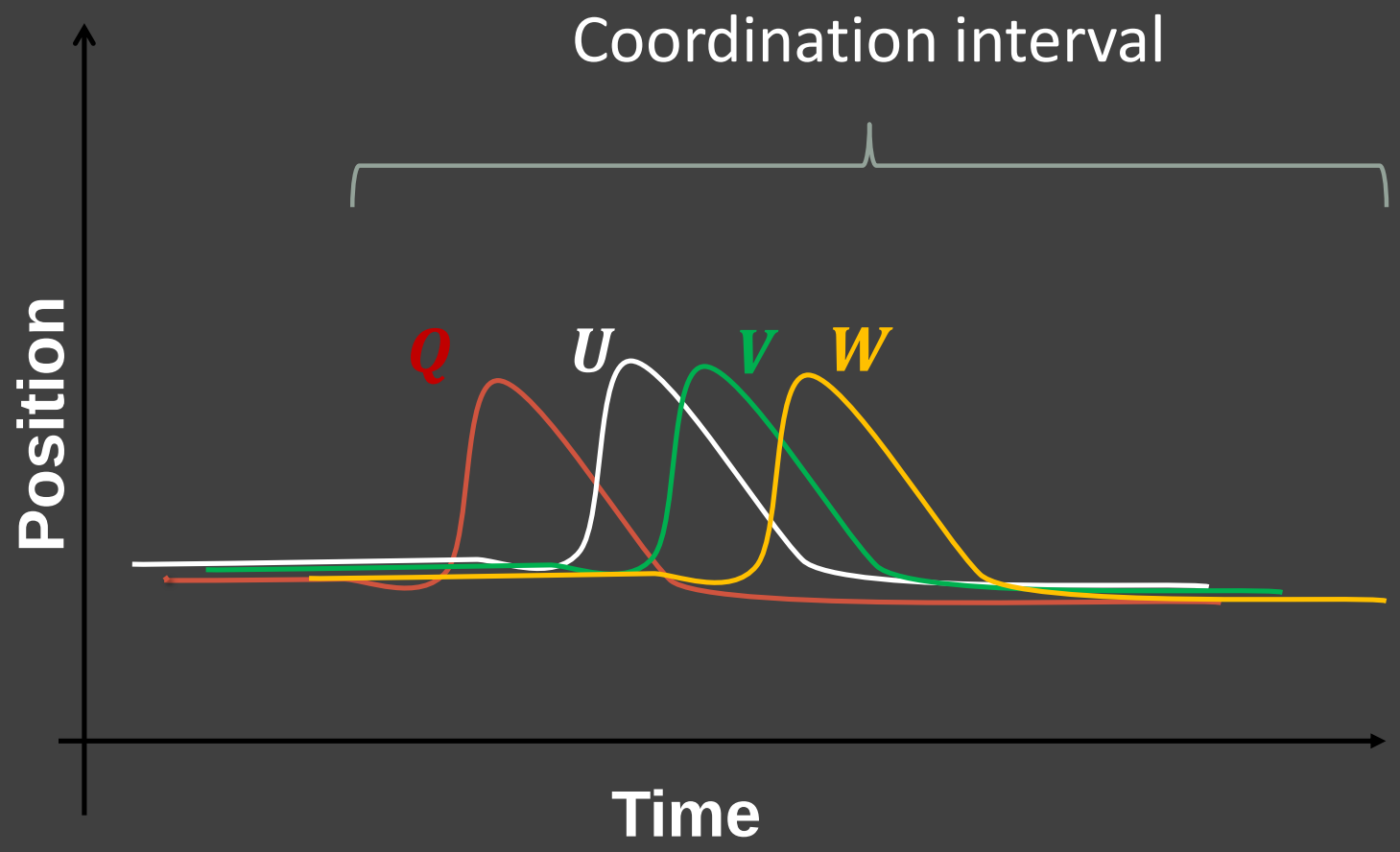
Following Network
Nodes: individuals
Edges: following relations

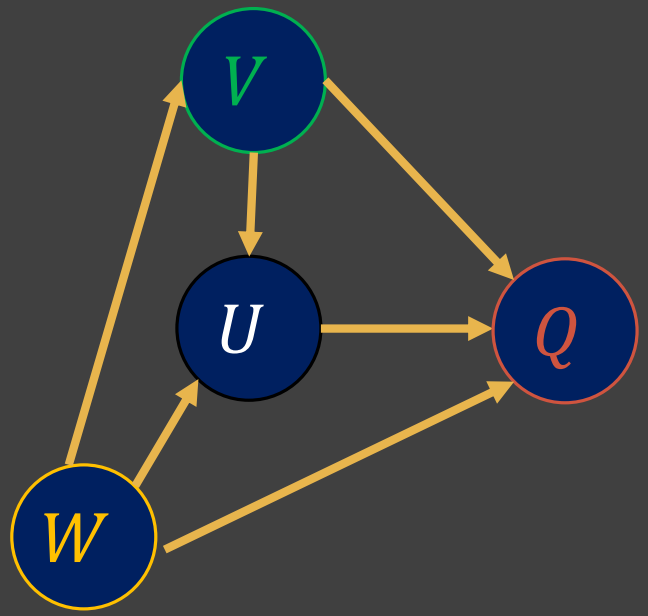
Time Series of U follows Q

The optimal warping path of DTW

Coordination

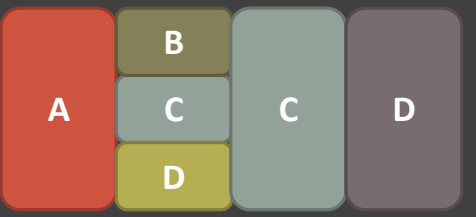






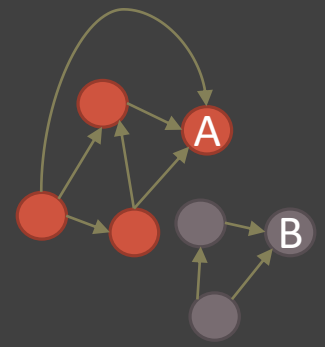
Following Network

Faction Detection



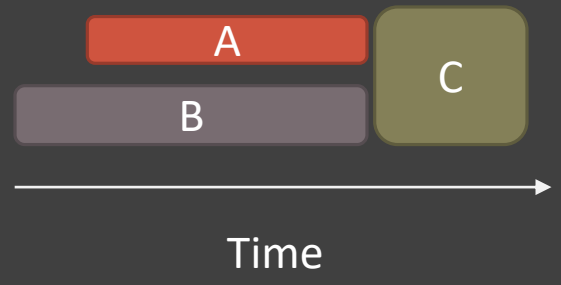
Faction definition

Definition 8 (Faction) *Given a set of time series $\mathcal{U}$, a subset $F \subseteq \mathcal{U}$ at time t is maximally coordinated, if F is coordinated and there is no other coordinated set $F' \subseteq \mathcal{U}$ where $F \subset F'$. We call such maximally coordinated F a faction at time t.*



Following network

Definition 9 (Faction interval) *The* coordination interval *of a faction F or a faction interval is the maximal consecutive time interval $[t_1, t_2]$ such that F is coordinated for every $t \in [t_1, t_2]$.*



Faction Initiator Inference Problem

Problem 2: FACTION INITIATOR INFERENCE PROBLEM

Input : Set $\mathcal{U} = \{U_1, \ldots, U_n\}$ of m-dimensional time series

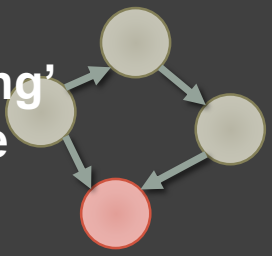
Output: A set of factions $\mathcal{F} = \{F_1, \ldots, F_k\}$, a set of coordinated intervals

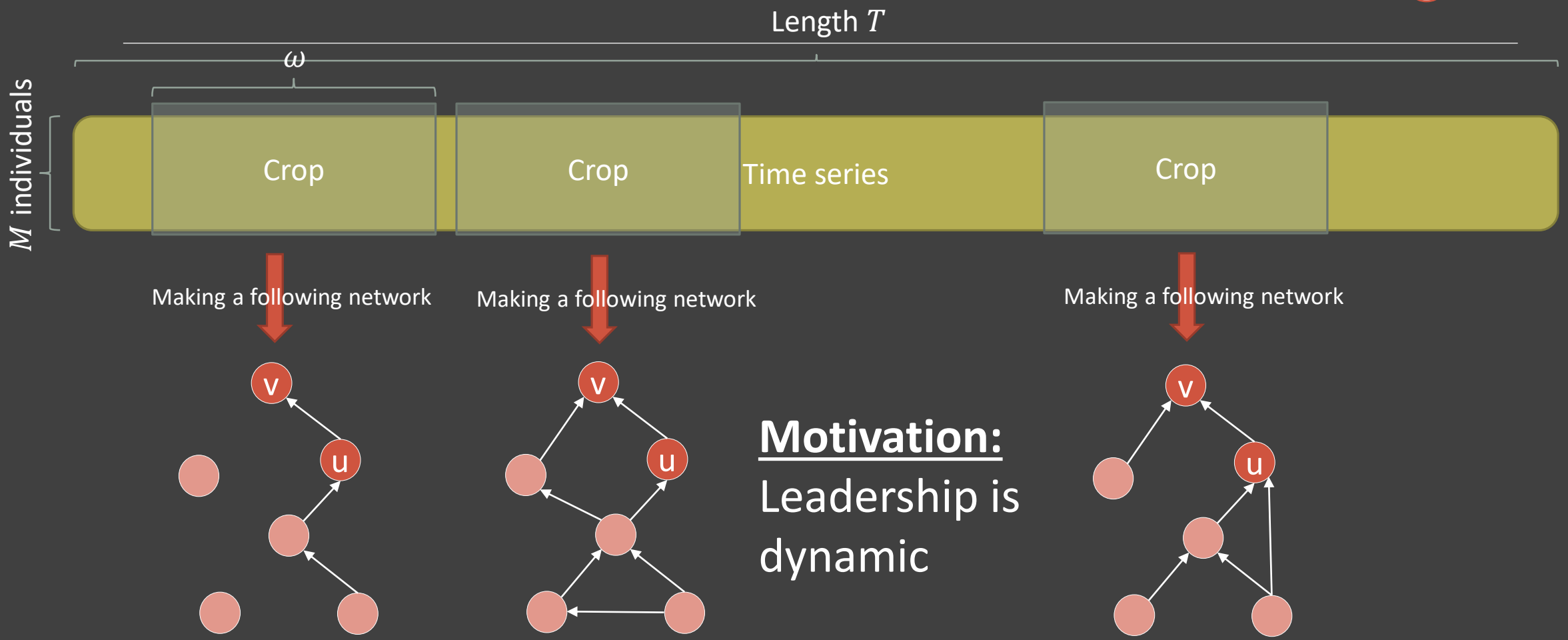
$\mathcal{T} = \{[t_1^1, t_2^1], ..., [t_1^k, t_2^k]\}$, and the set of initiator time series $\mathcal{L} = \{L_1, ...L_k\}$

where L_i initiated the coordination interval $[t_1^i, t_2^i]$ of the faction F_i

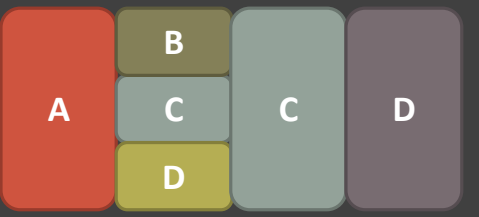
Dynamic following network

Dynamic 'Following' Network Inference





Motivation:
Leadership is dynamic



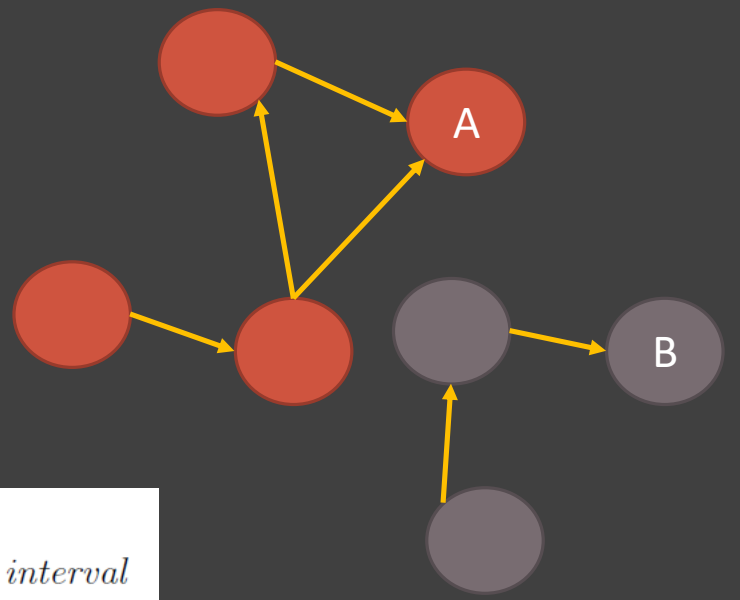
Faction Detection in Dynamic following network

Find initiators in following network

- Initiator L: zero outgoing degree

Find Members of each faction: BFS

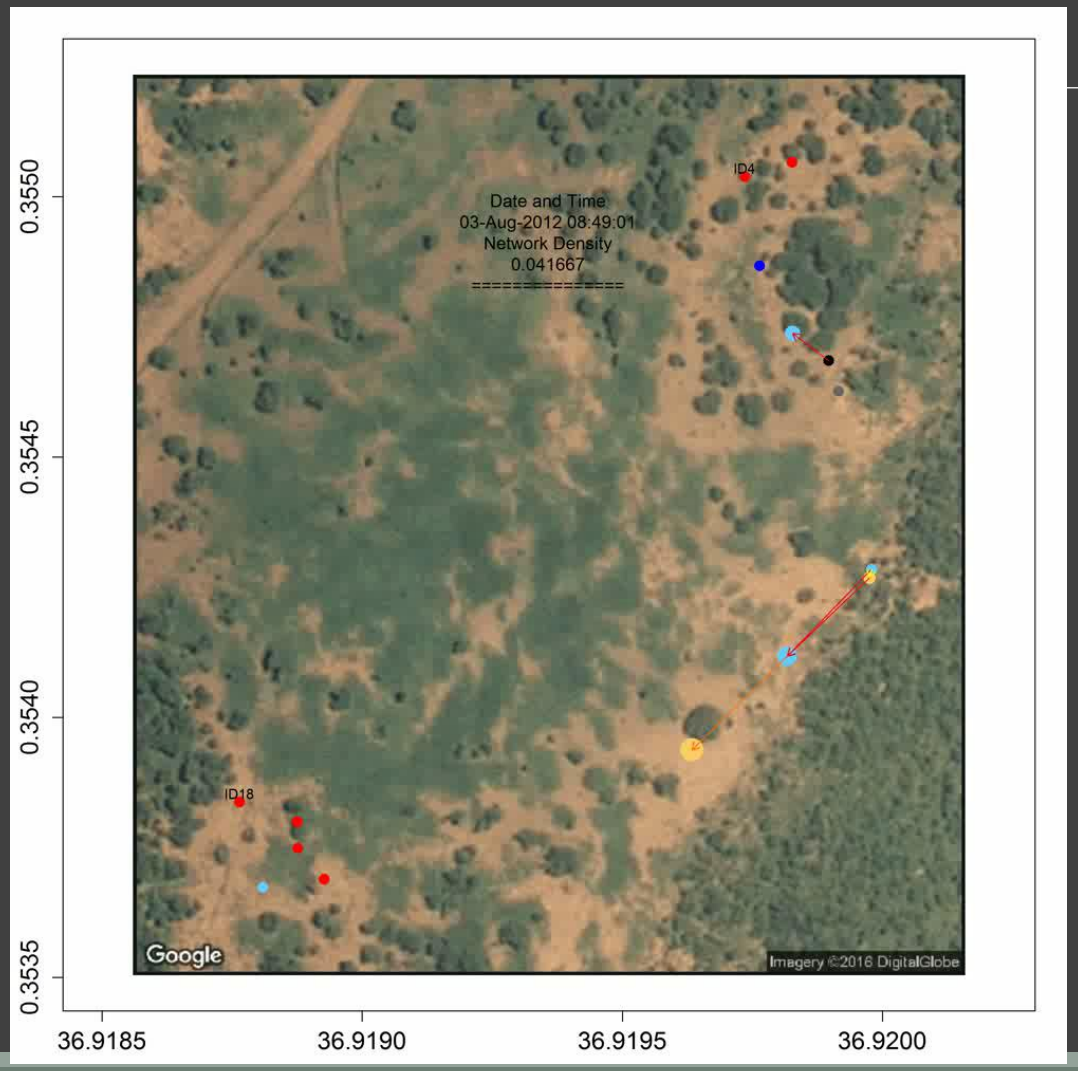
- Member of faction has a path reaches to L

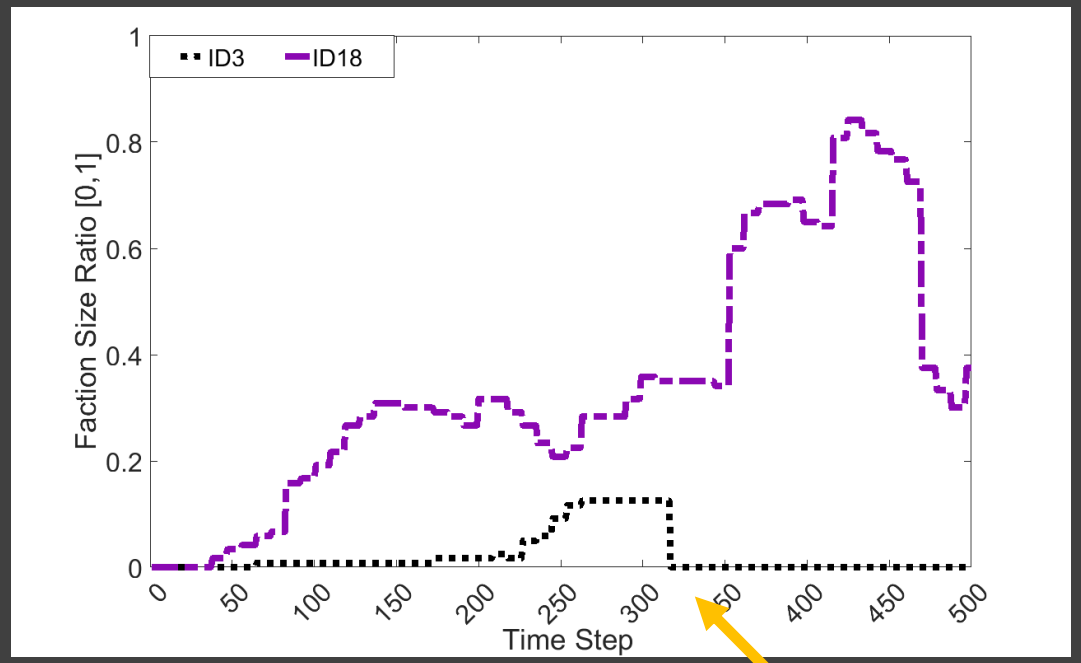


Definition 11 (Relaxed faction interval) *Let $\mathcal{U}$ be a set of time series, the time interval $[t_1, t_2]$ is a faction interval of initiator L if for all $t \in [t_1, t_2]$, there exists a faction F_t such that F_t has L as its initiator and $|F_t| > 1$.*

Results

Case study: merging event of baboon troops.





Faction size ratio = $\frac{|E_f|}{\binom{|V|}{2}}$

320th time step

Faction prediction result: simulation data

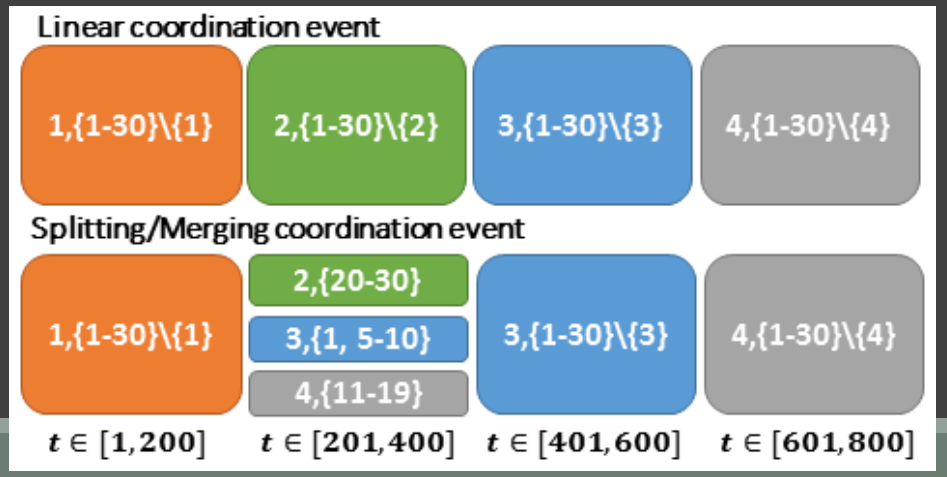
Factions and Leaders identification on simulation models

Dataset	Leadership F1-score		Assignment Acc.	
	mFLICA	FLOCK	mFLICA	FLOCK
DM-L	**0.94**	0.92	**0.89**	0.86
DM-MS	**0.94**	0.91	**0.86**	0.84
HM-L	**0.94**	0.91	**0.94**	0.86
HM-MS	**0.95**	0.90	**0.86**	0.81
IC-L	**0.91**	0.86	**0.86**	0.80
IC-MS	**0.89**	0.85	**0.79**	**0.79**
CM-L	**0.82**	0.64	**0.83**	0.64
CM-MS	**0.75**	0.67	**0.64**	0.55

Faction prediction result: school of fish

A school of fish inference median accuracy over 24 trails

Method	Trained fish factions	Trained fish leaders
mFLICA	0.90	0.88
FLOCK	0.37	0.27



Summary

We formalized Faction Initiator Inference Problem

Propose Average Coordination Measure: degree of coordination (time window inference)

- See the detail at my poster!

Propose Complex Leadership inference Framework in Time Series: mFLICA

1. Detecting multiple factions events
2. Identifying initiators of each faction
3. Infer time window that maximizes the average coordination measure.

Our results show that,

- Leadership identification: mFLICA can infer all types of complicated leadership process: Linear and Splitting/Merging Coordination Events .
- mFLICA can infer trained fish accurately.
- mFLICA can detect the group merging event of the baboon troop

Q&A