Trajectory Grouping Structure

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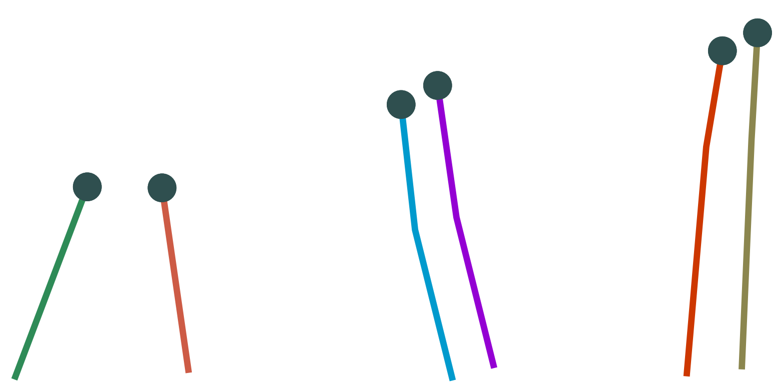
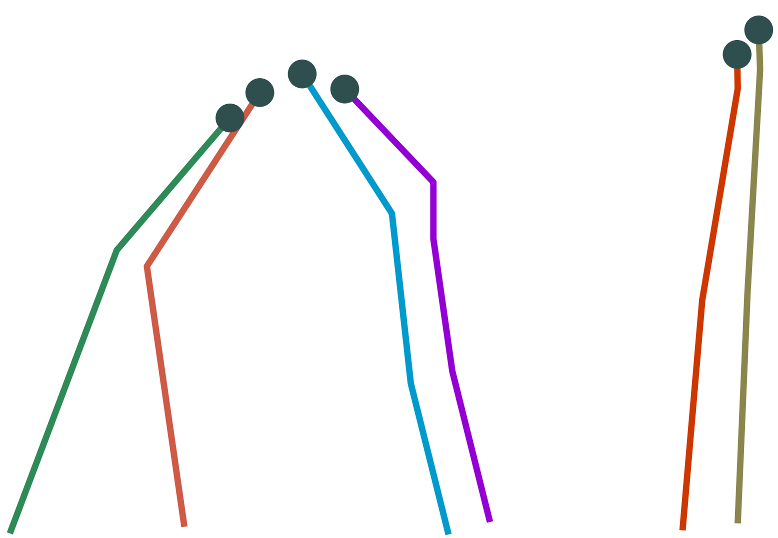
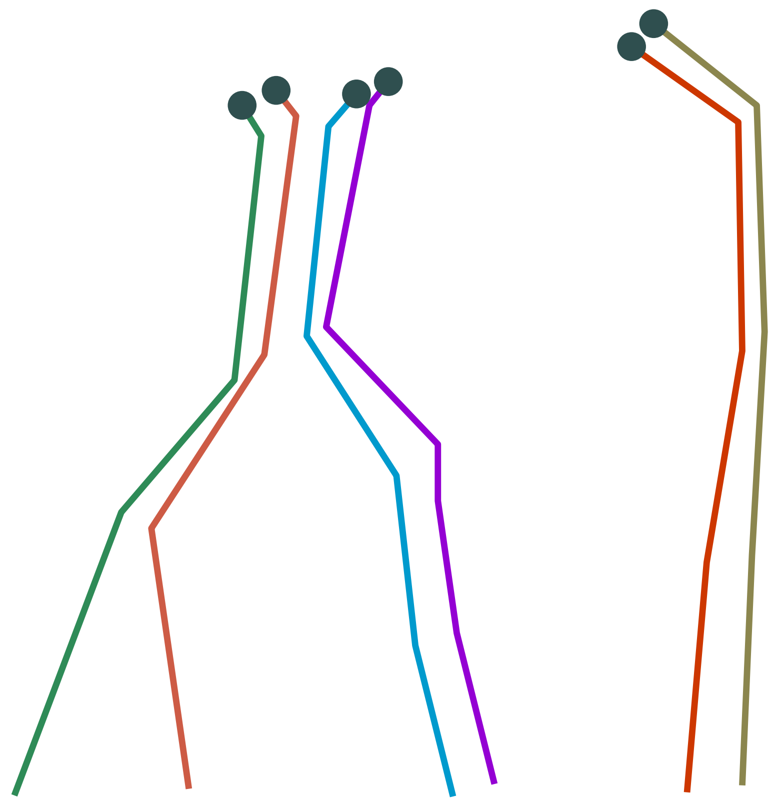
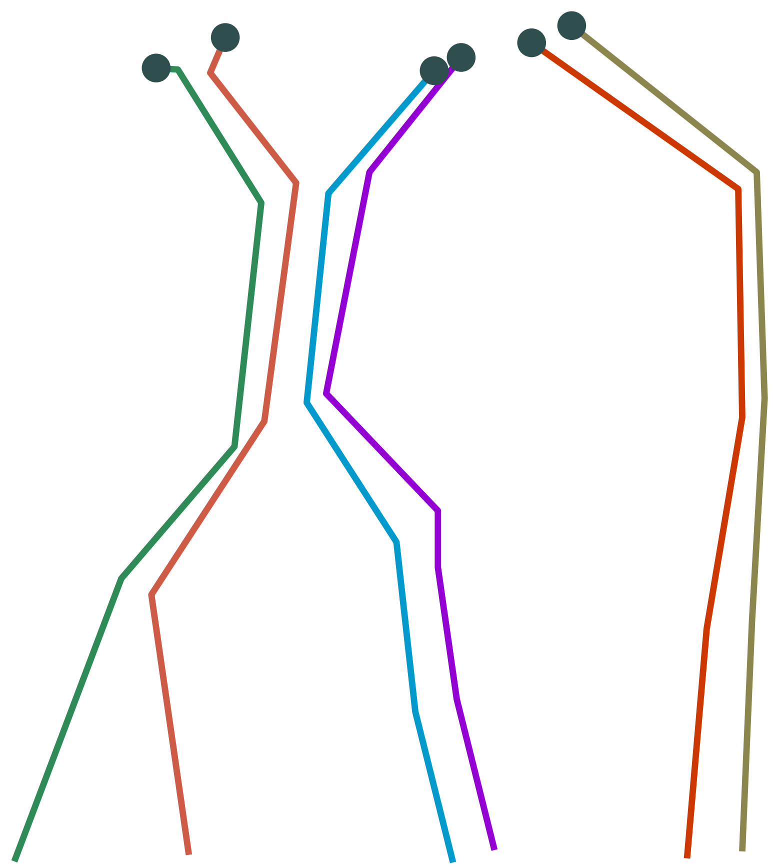
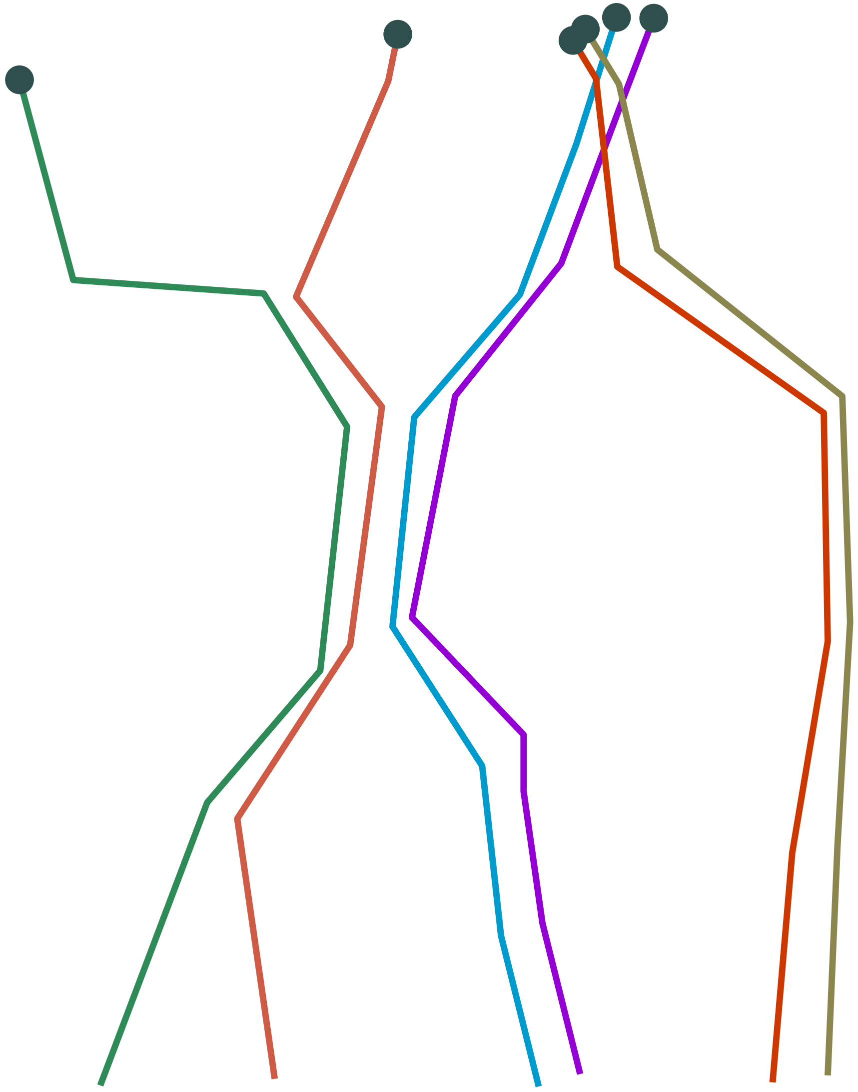
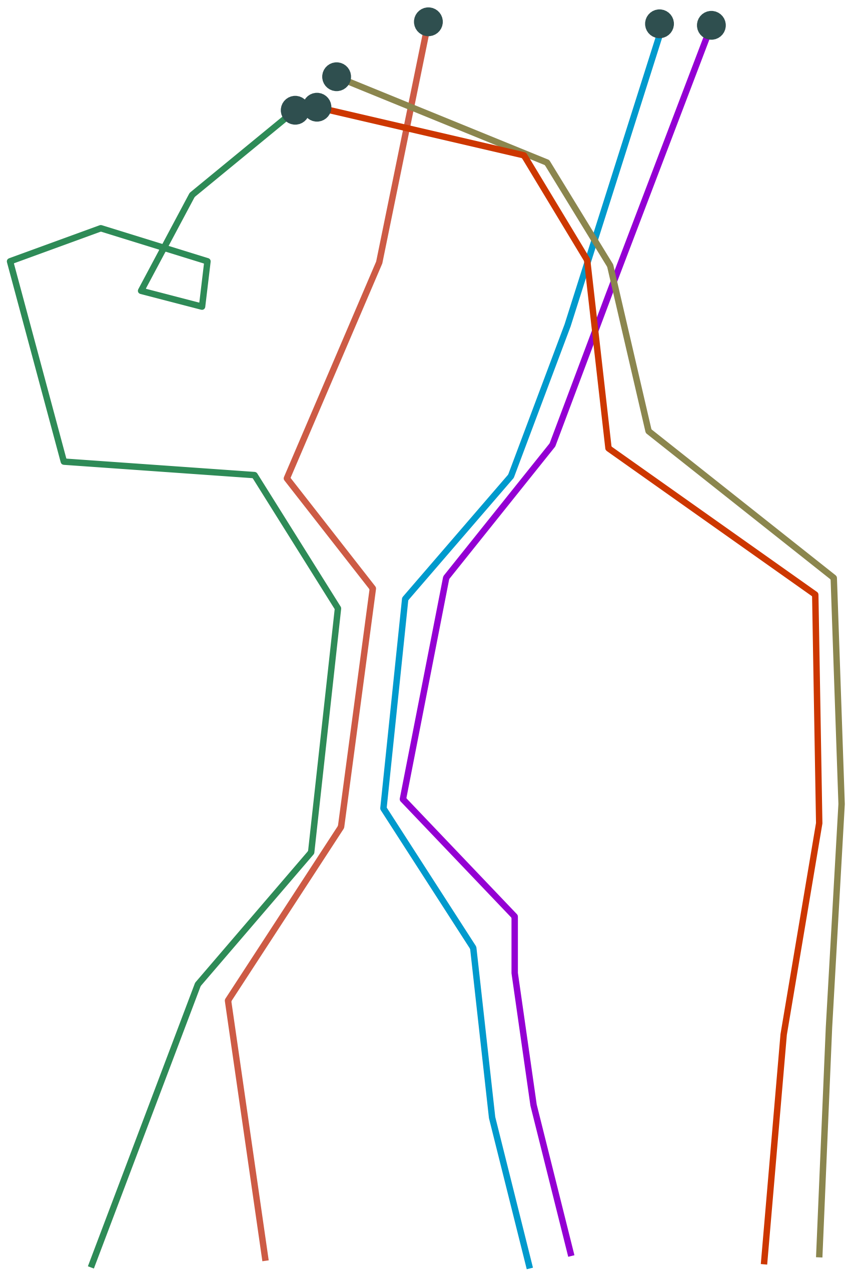


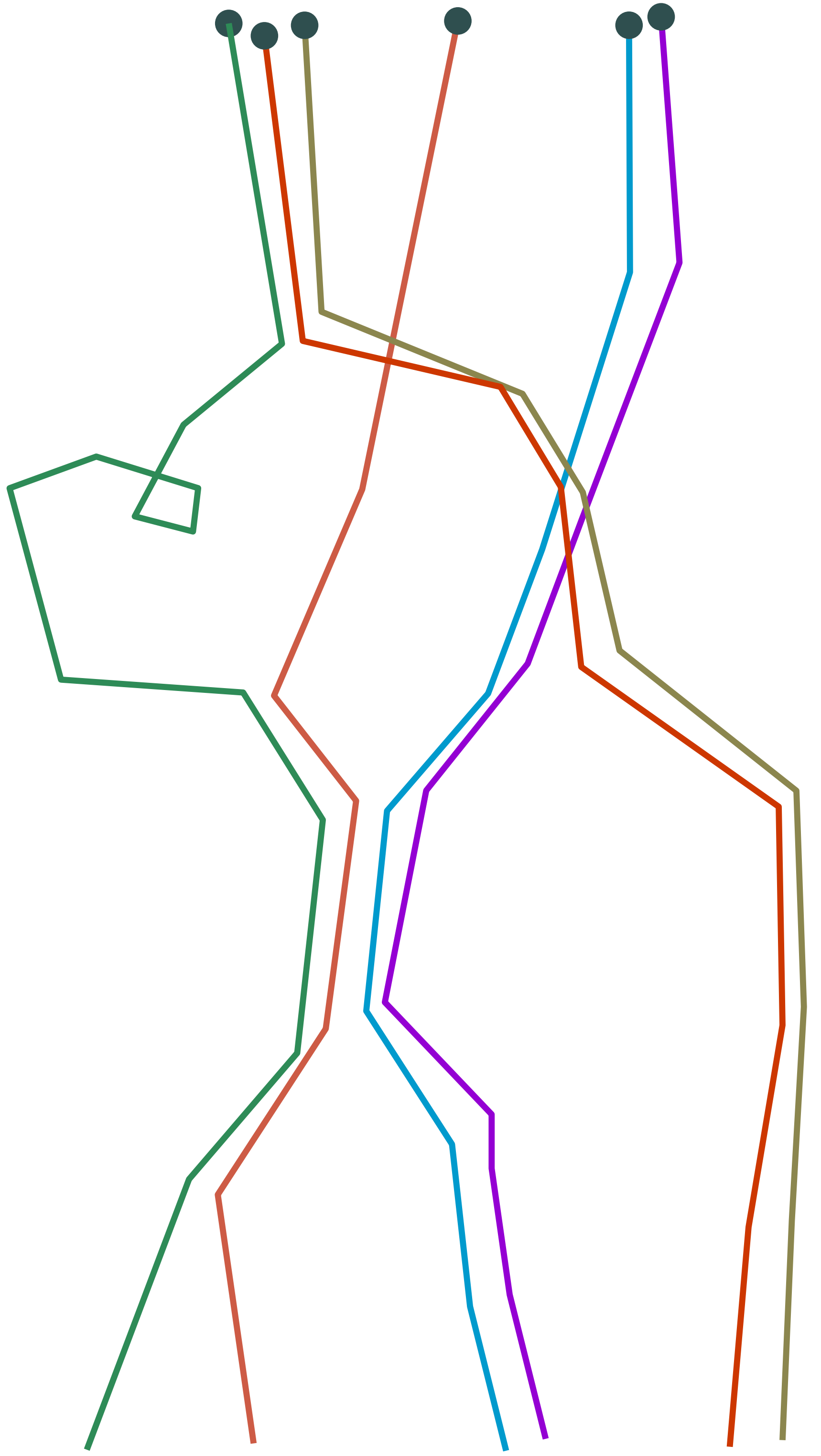


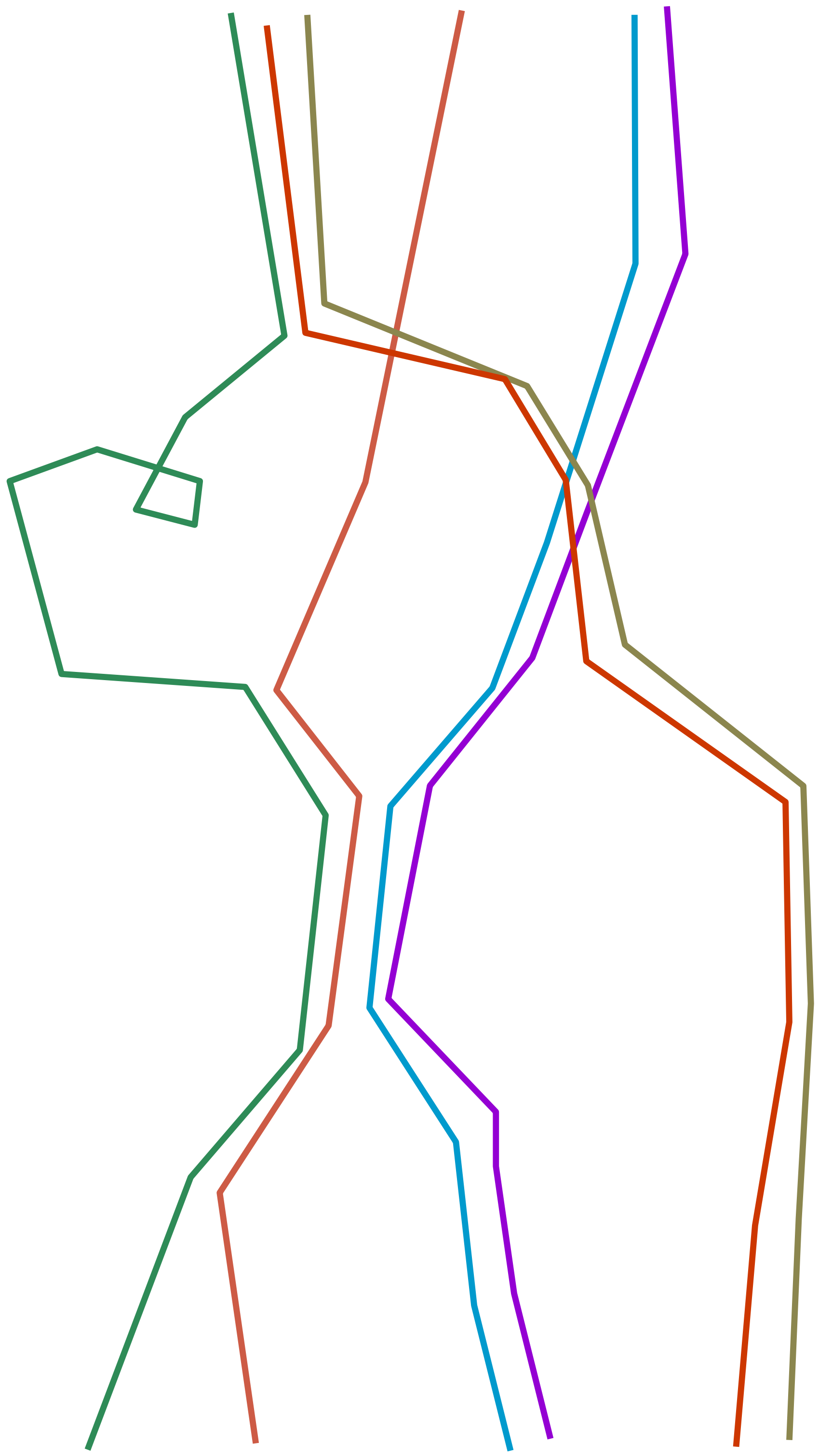








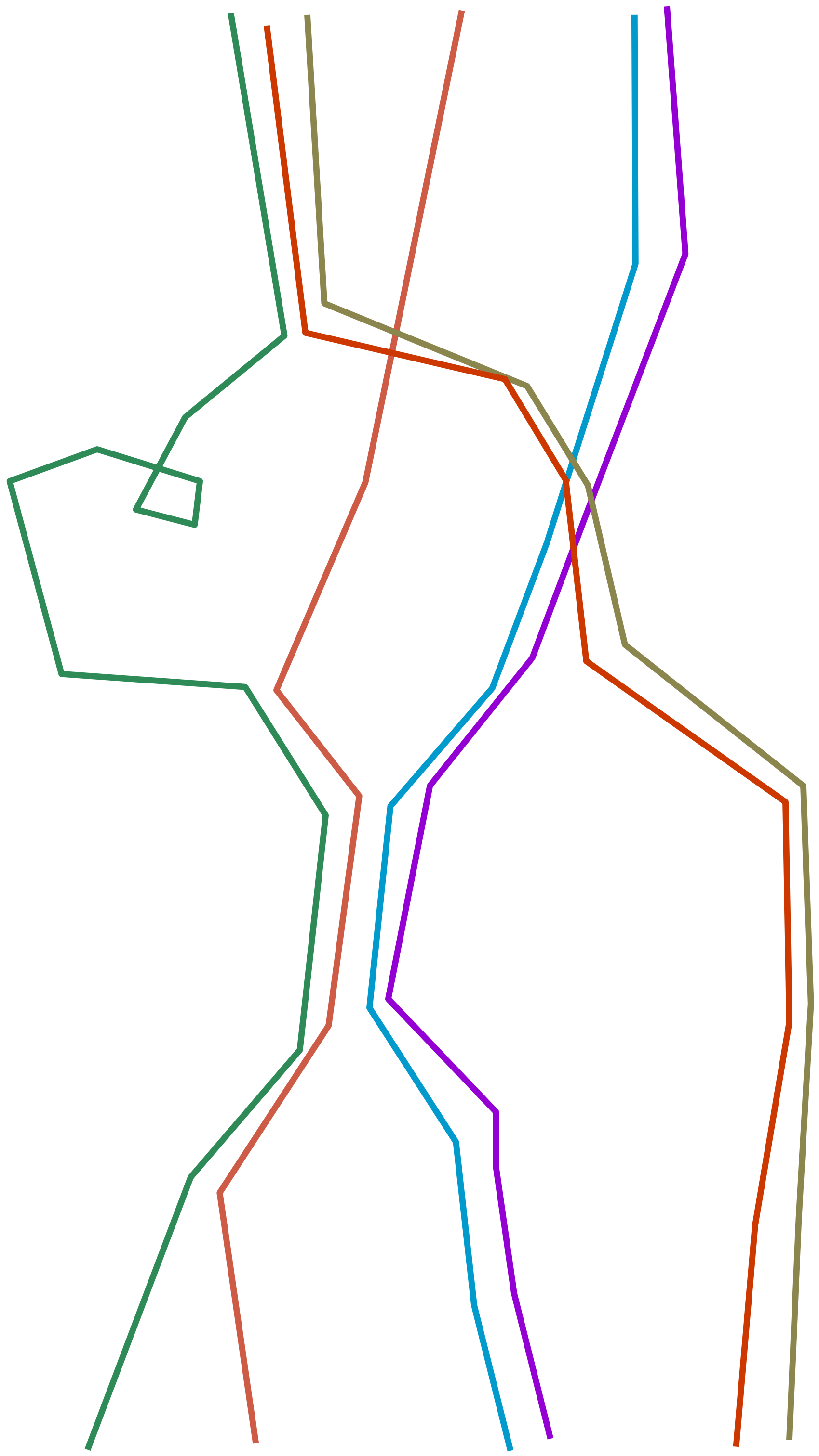




Groups

We want to find groups,

and how the groups change over time.



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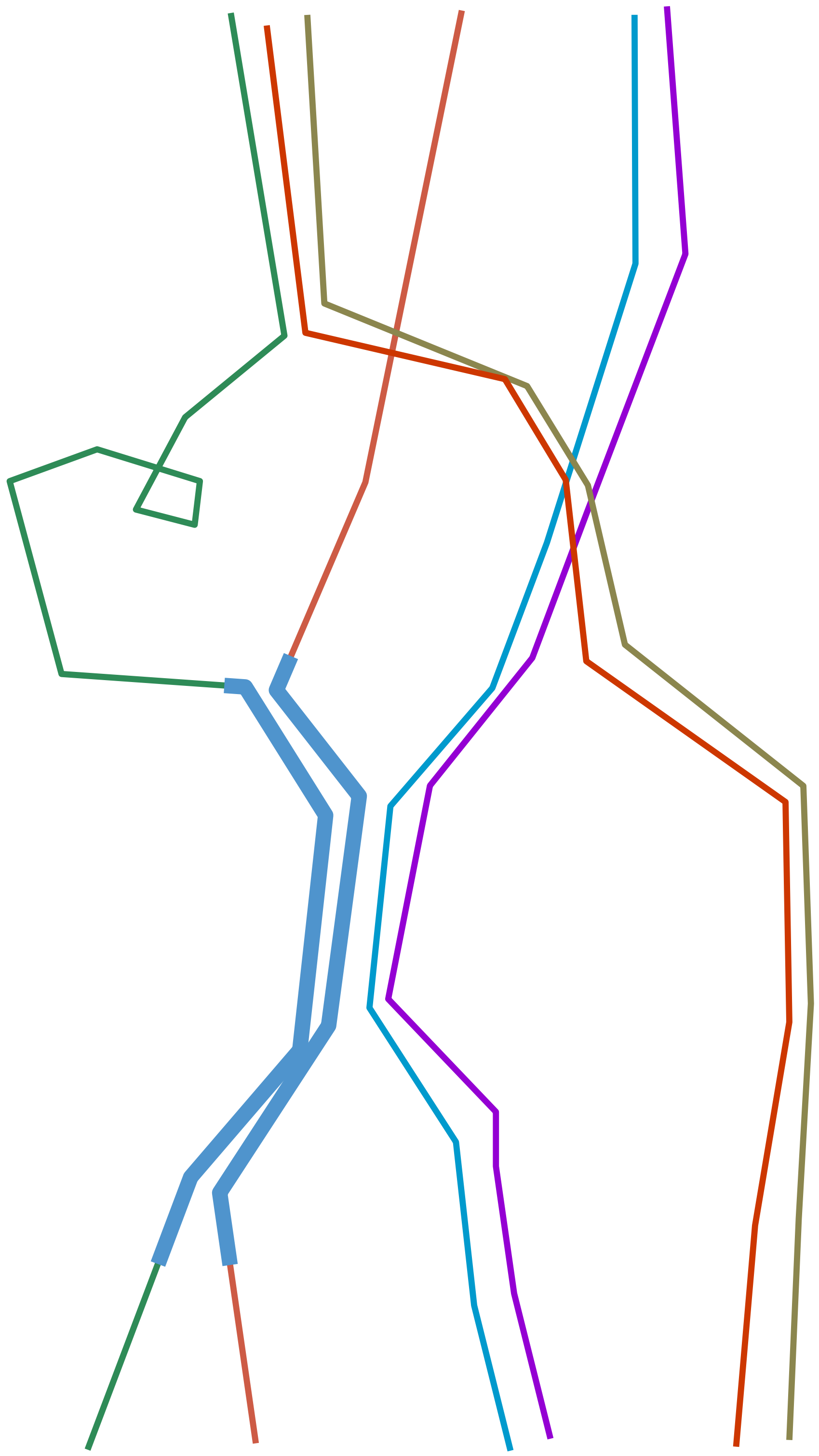

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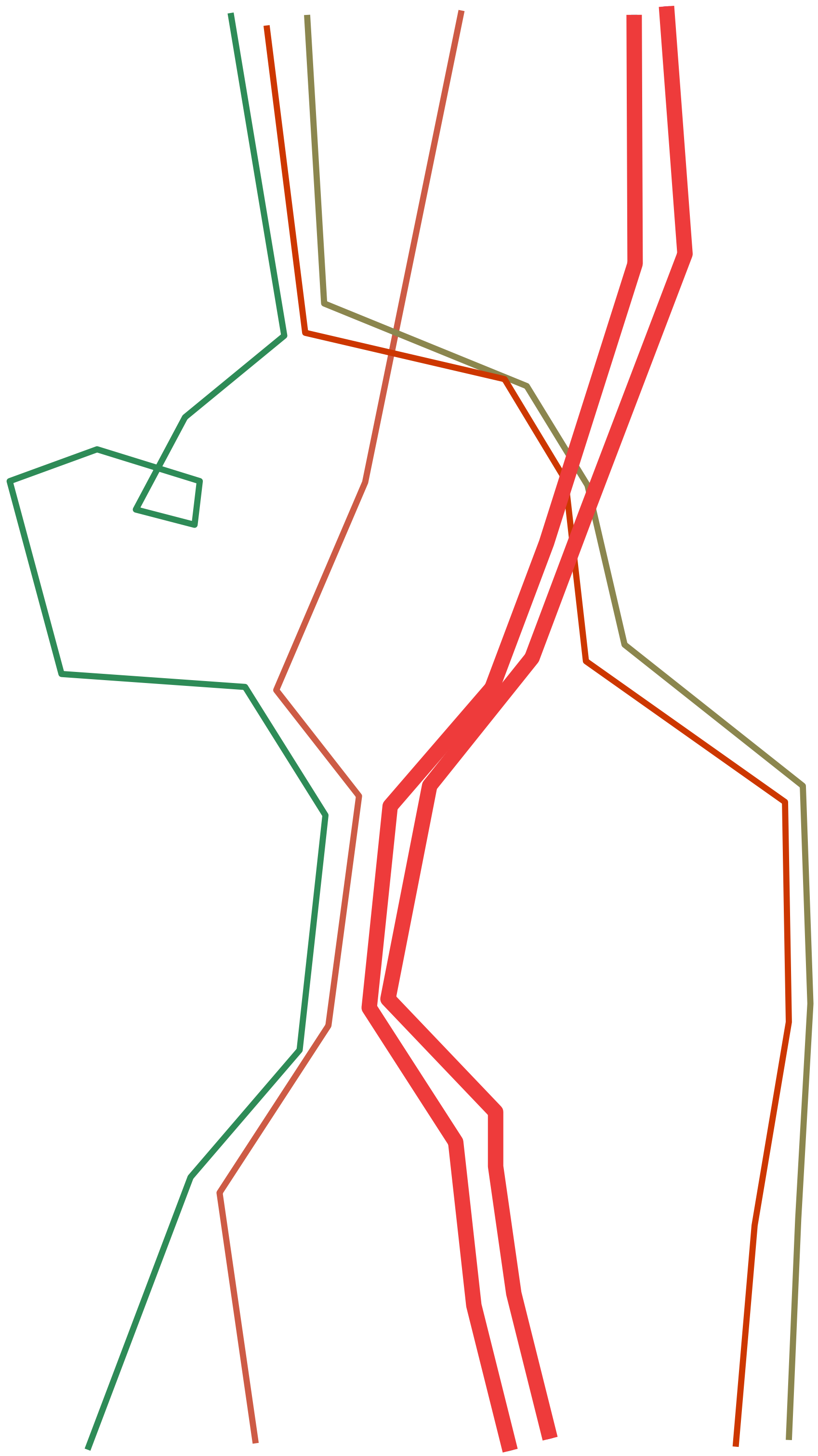

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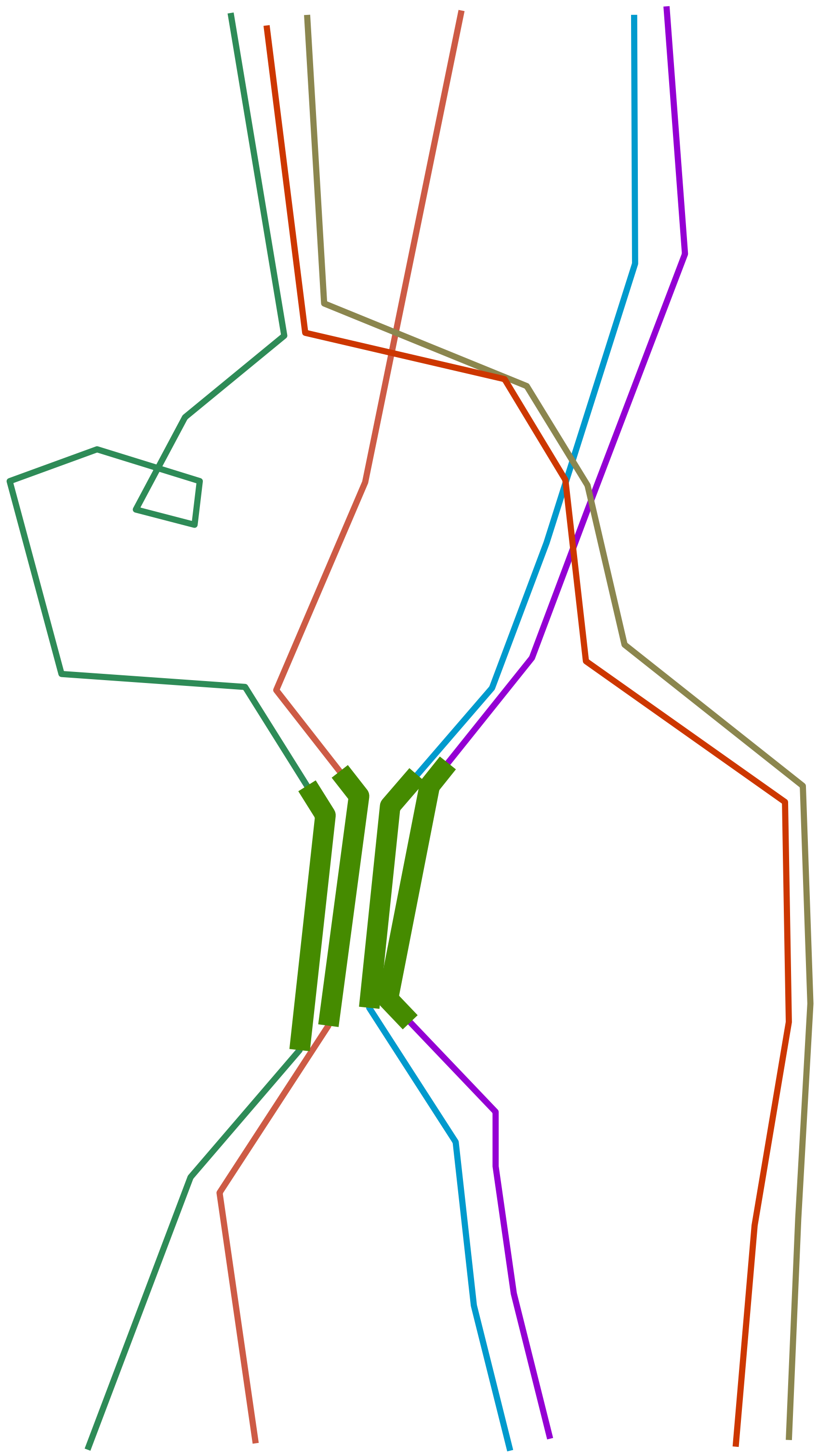

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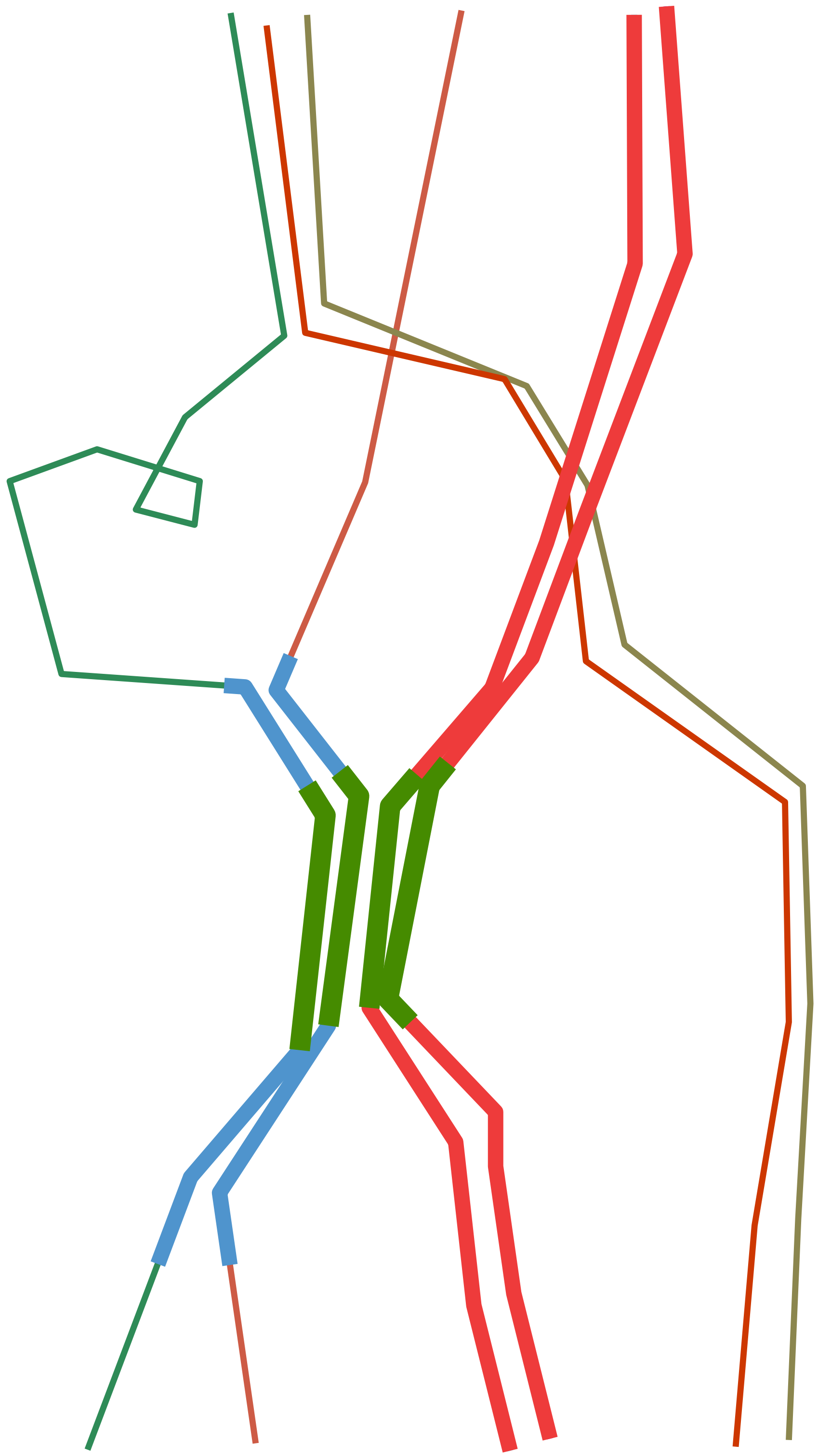

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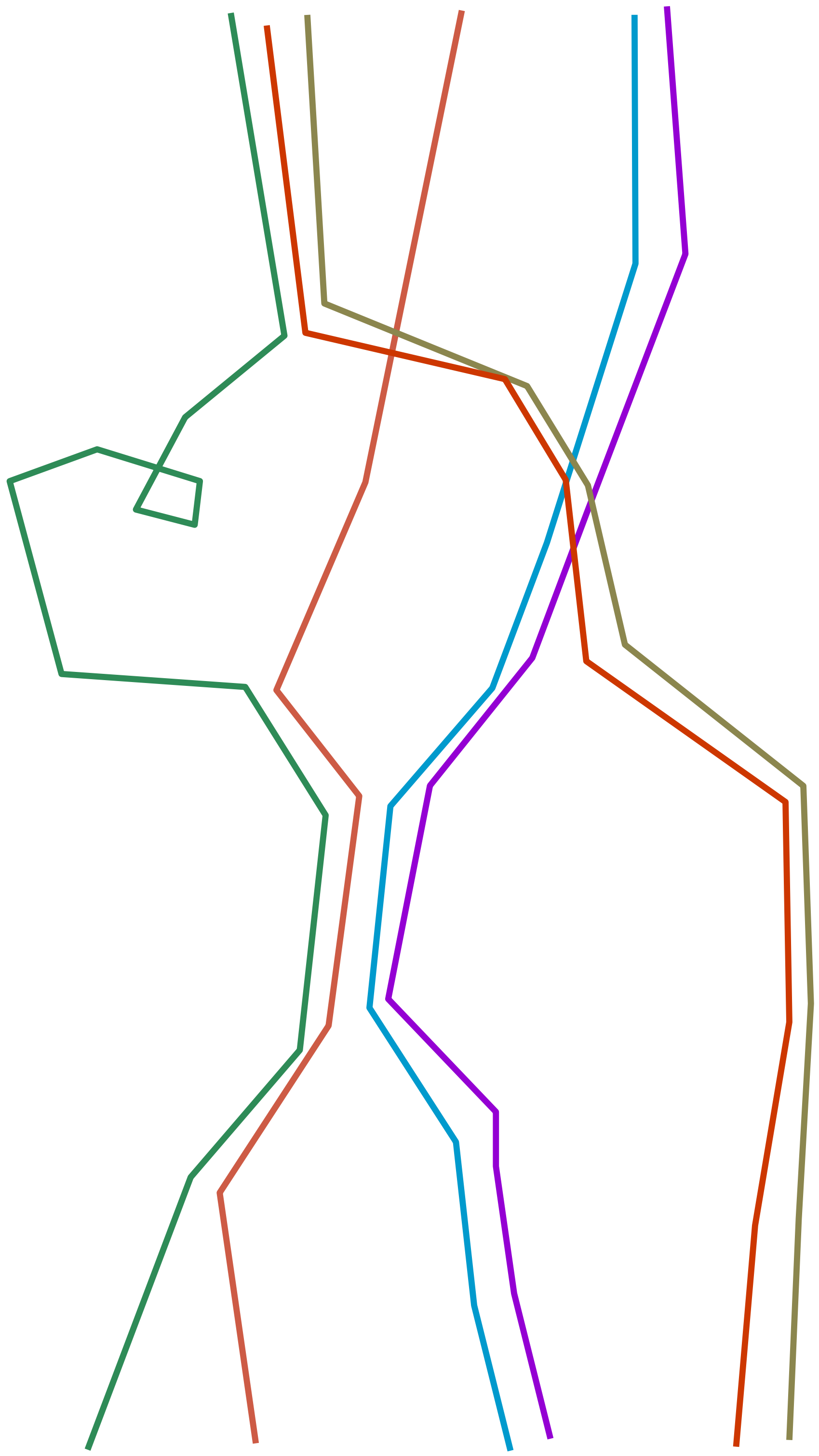
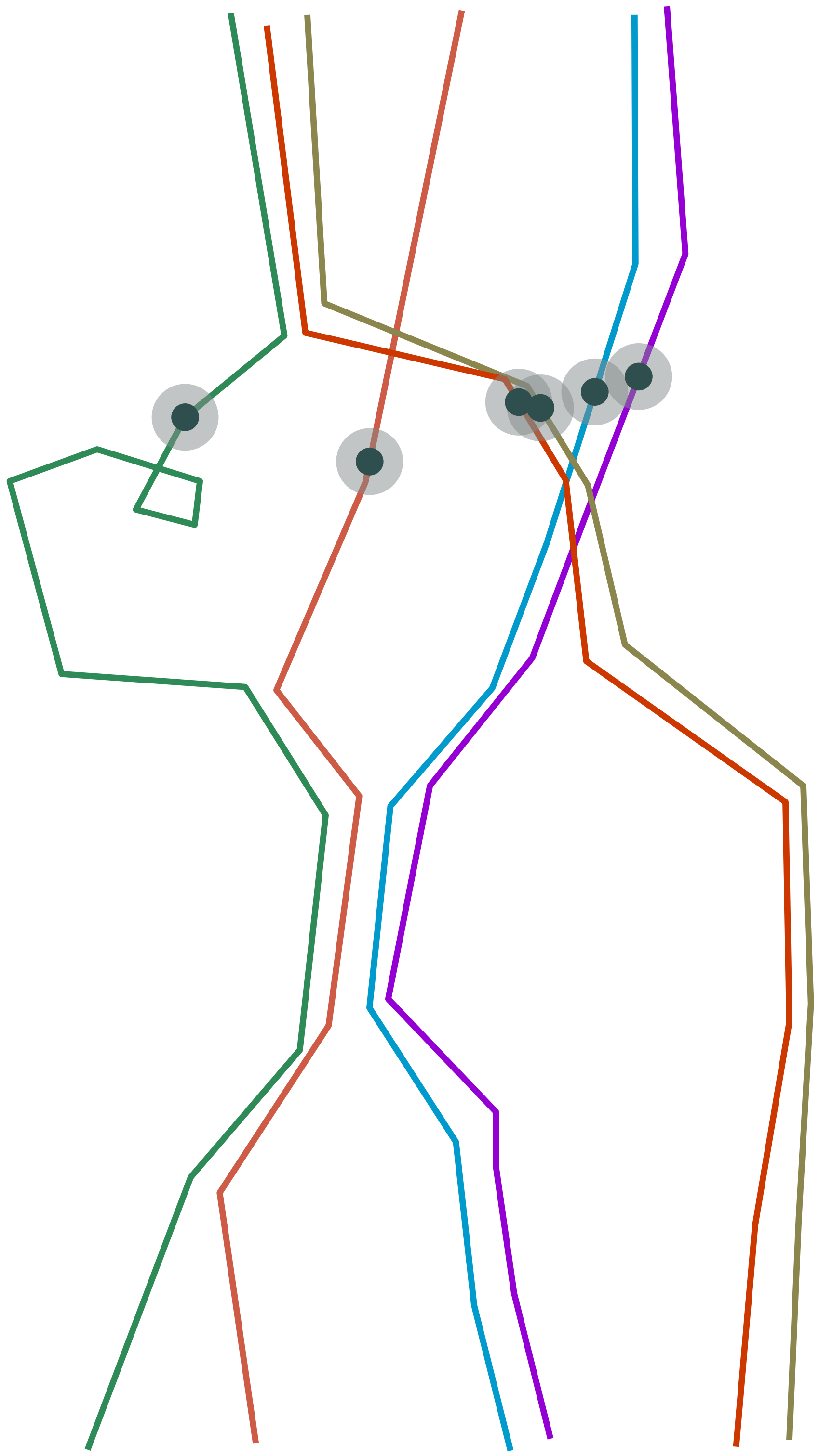
> Trajectory Grouping Structure



Groups

Group parameters:

- min group size: m
- min duration: δ
- max distance between entities: ε



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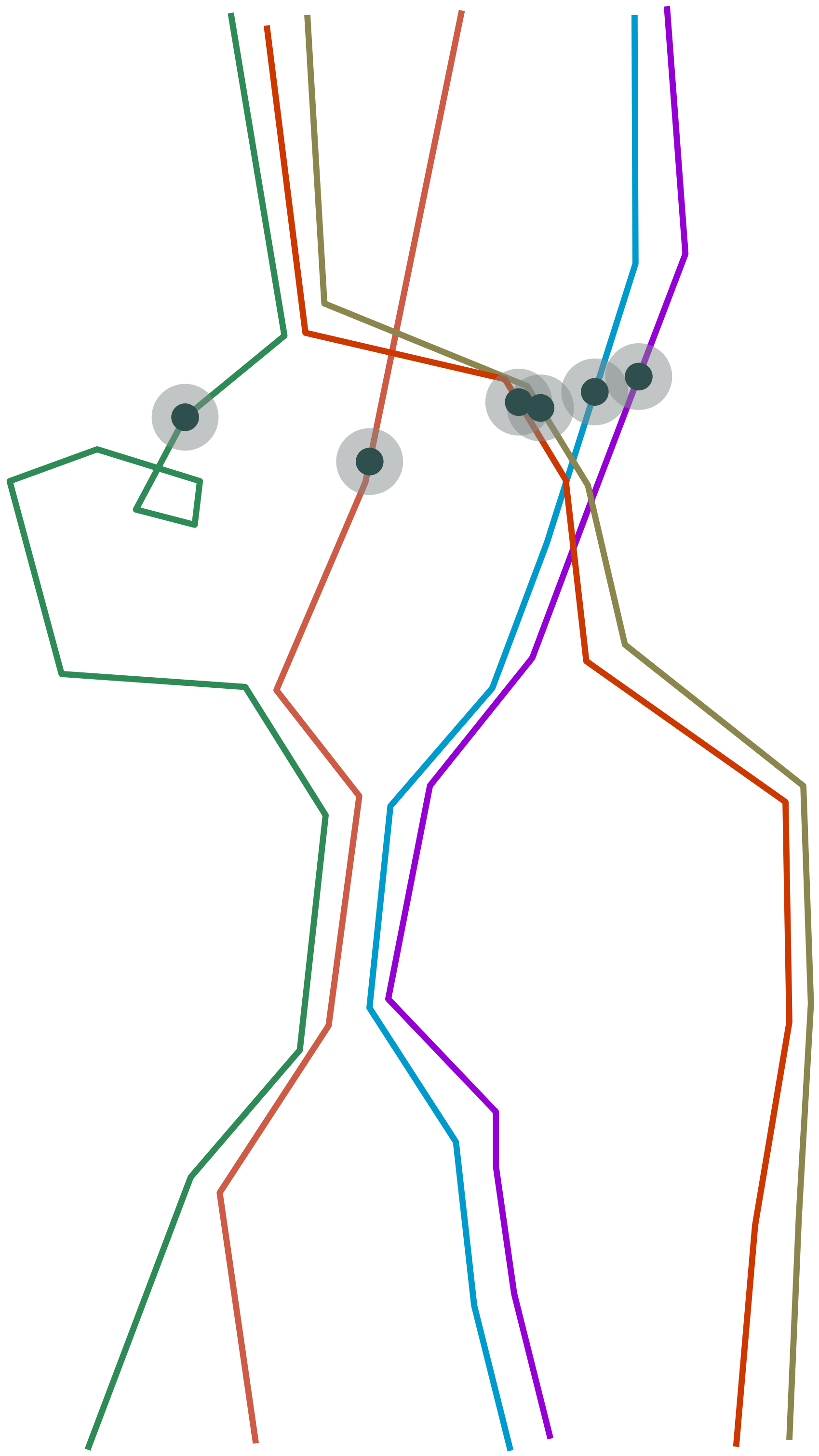

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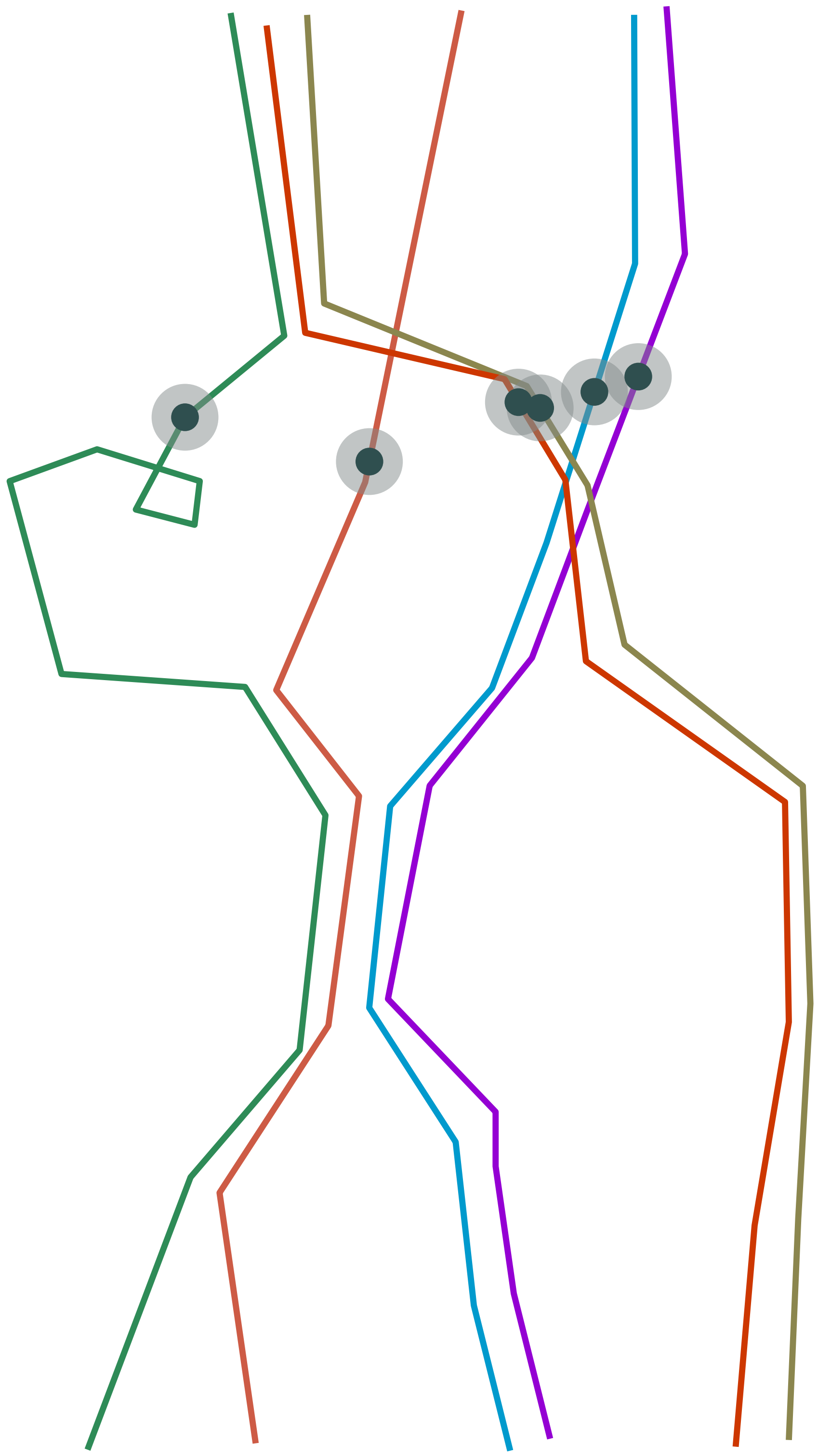
The grouping structure should allow study of groups at different scales.



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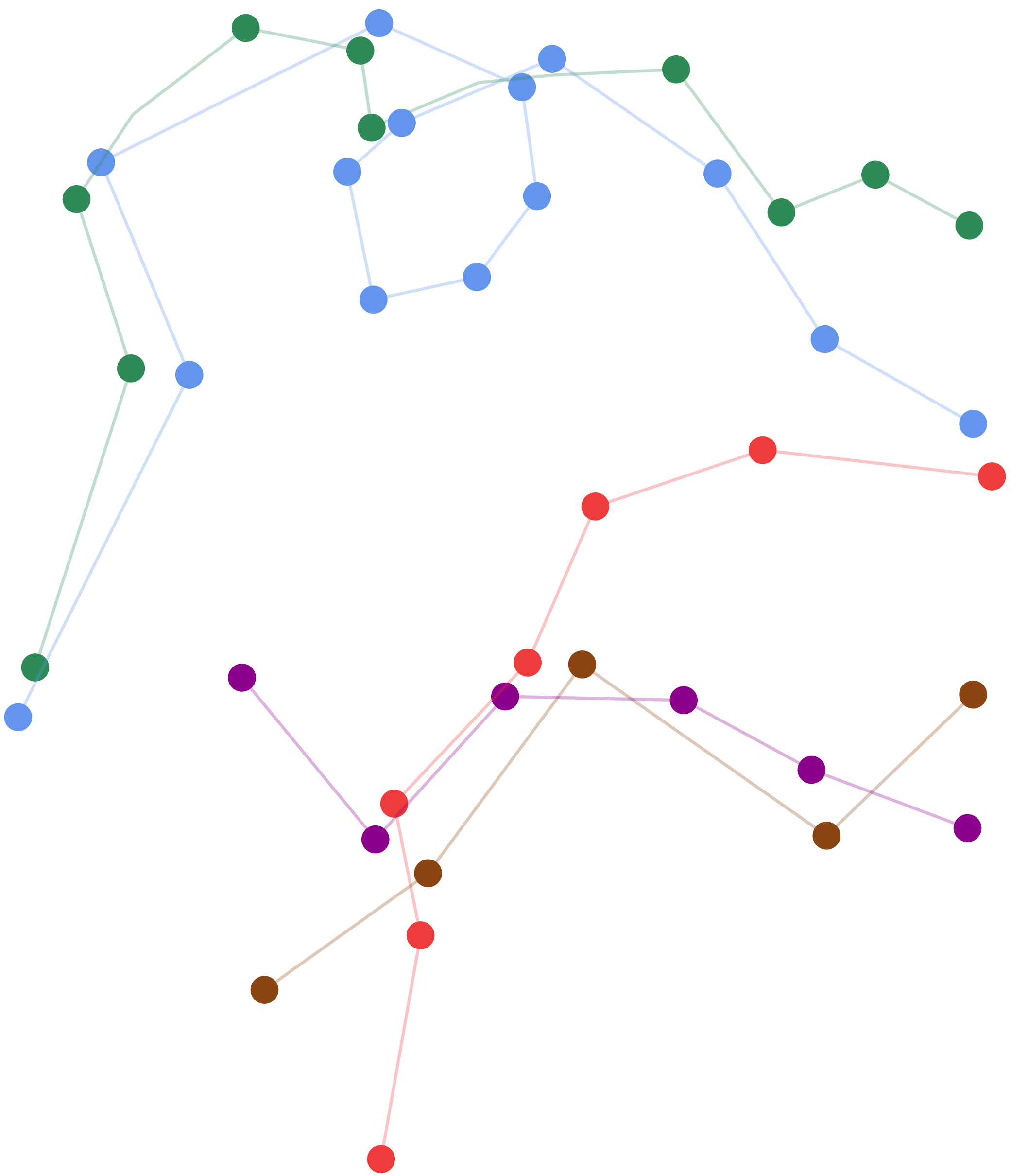
Computational Topolgy

Related Work

convoys, moving clusters, mobile groups, swarms, flocks, herds, ...



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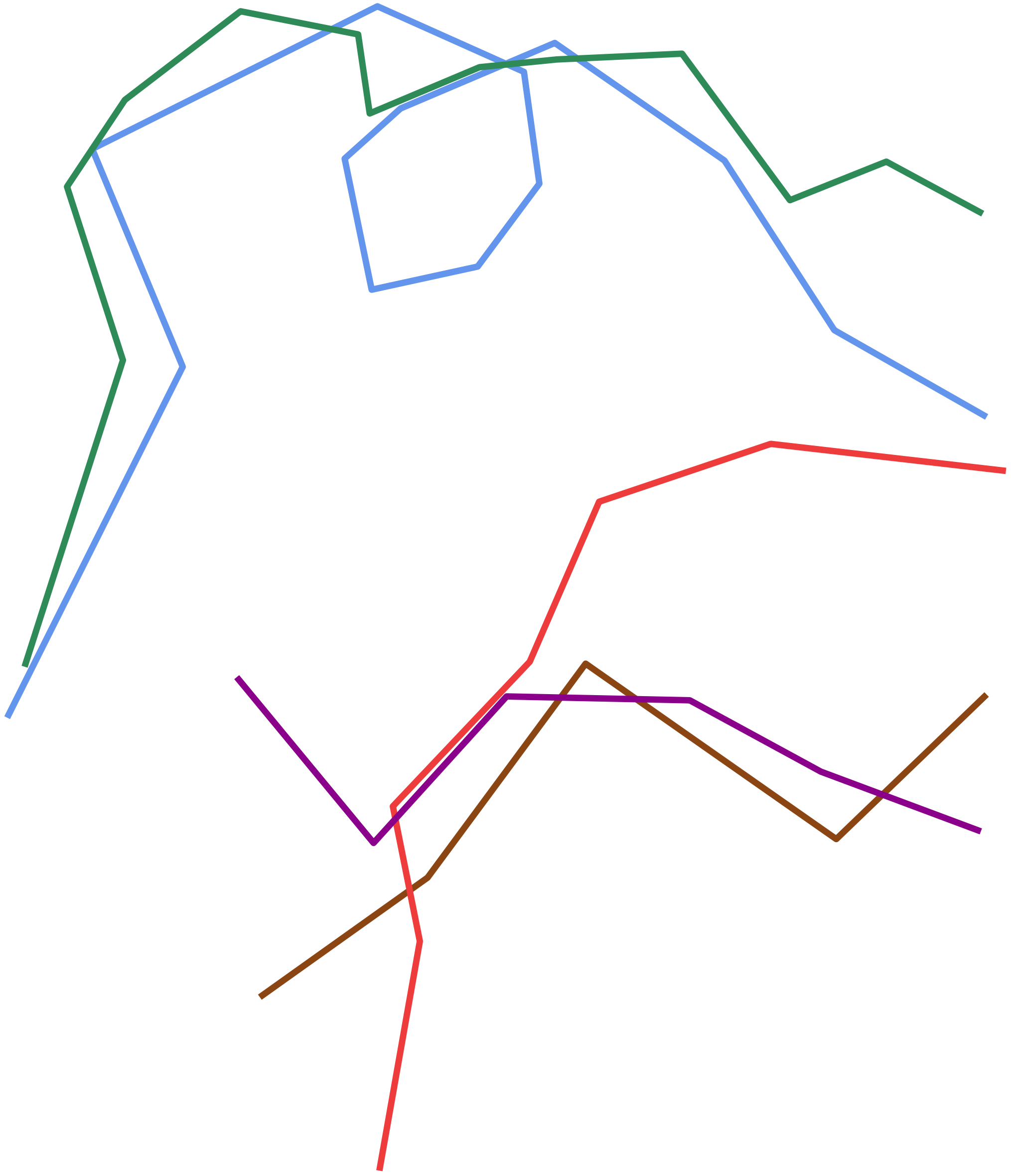
Discrete trajectory data



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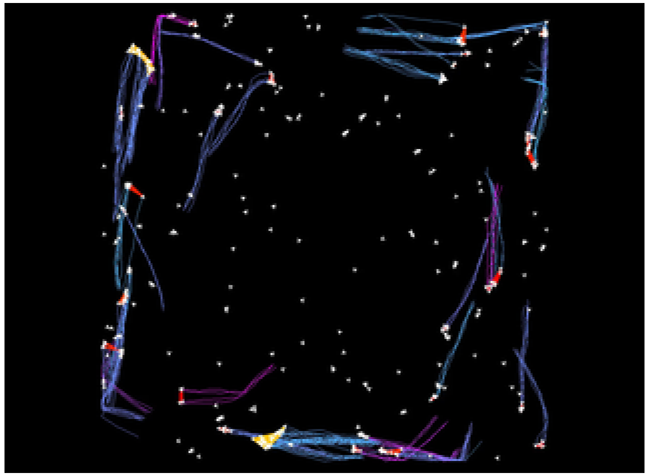
Continuous trajectory data

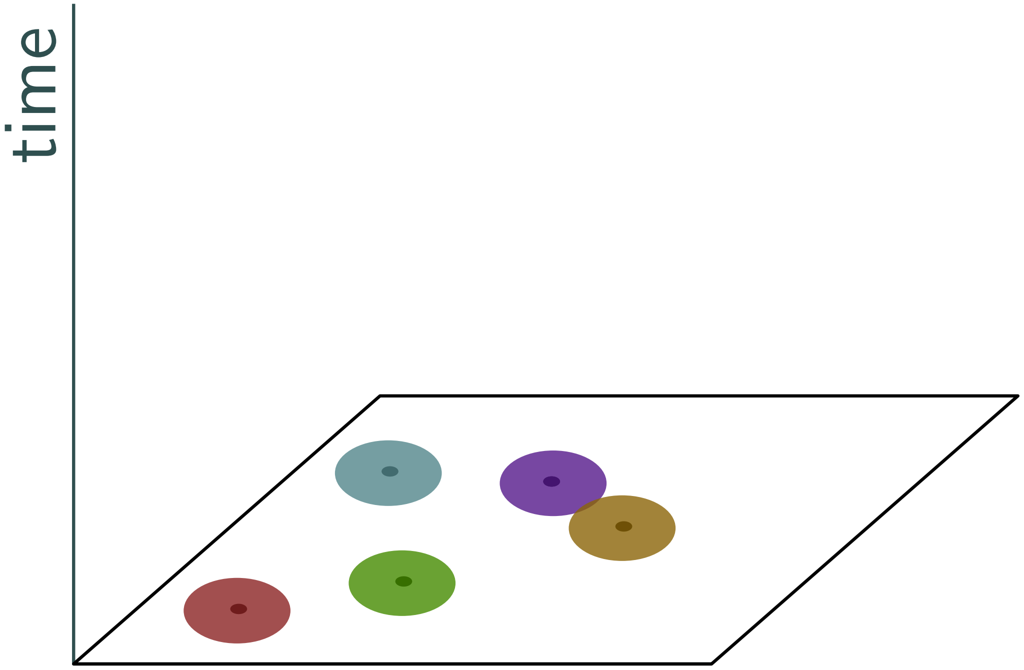


Related Work

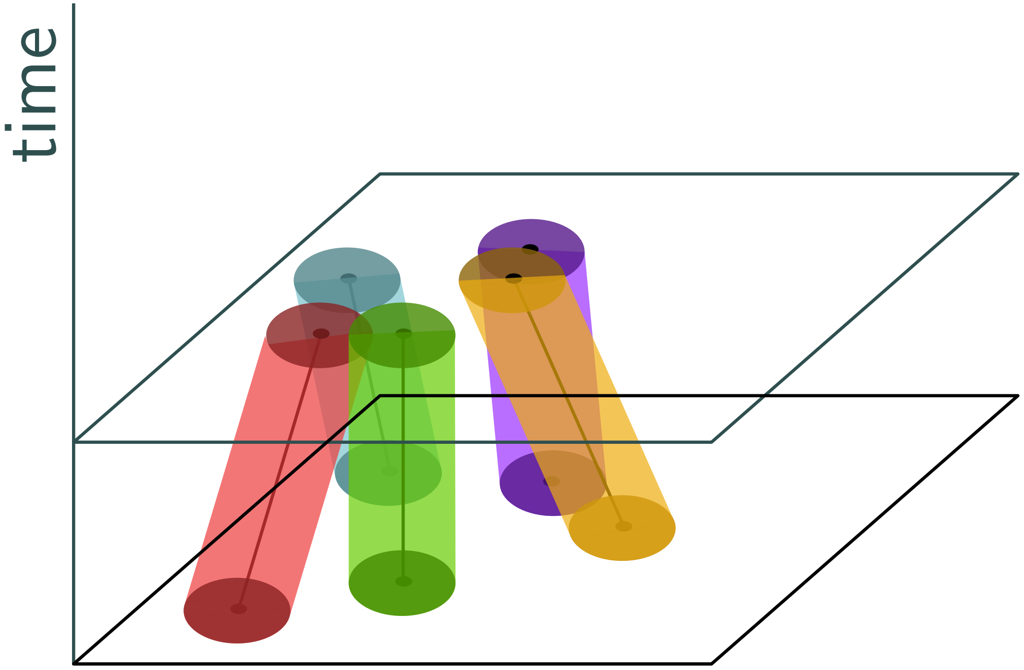
convoys, moving clusters, mobile groups, swarms, flocks, herds, ...

Continuous trajectory data

We provide an experimental evaluation.



Consider tracing ε-discs over the trajectories.



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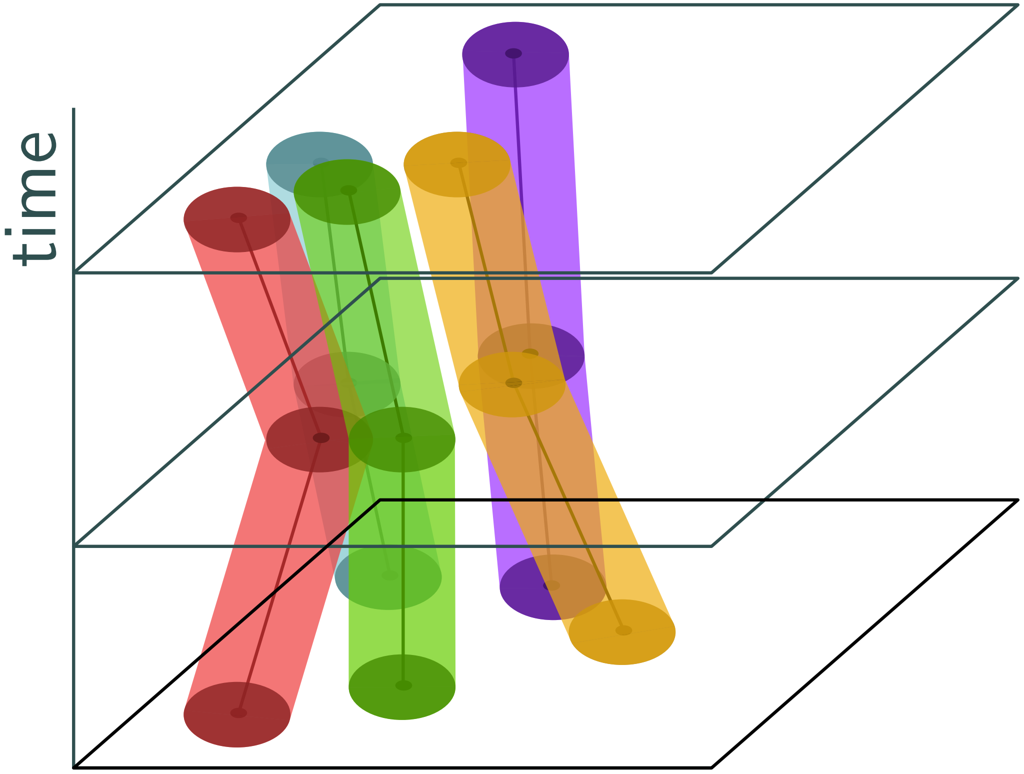

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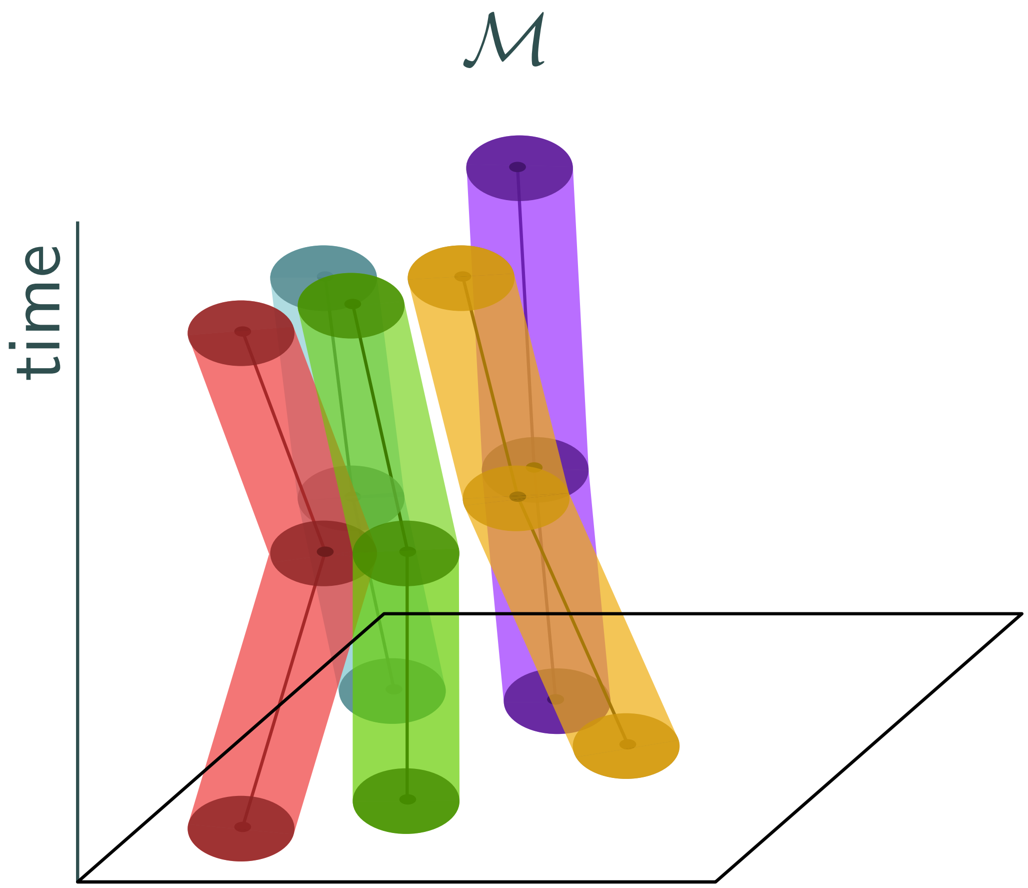
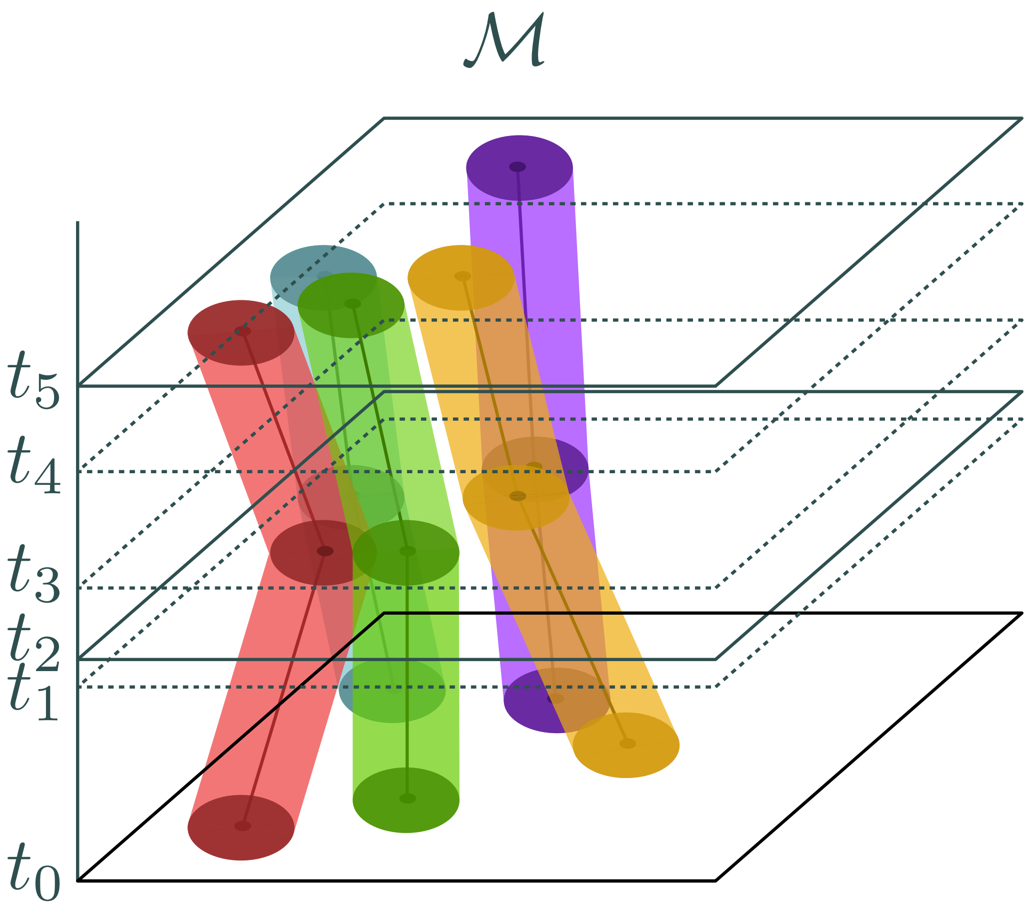


Consider tracing ε-discs over the trajectories.

Each entity produces a "tube". Let $\mathcal{M}$ be the union of those n "tubes".



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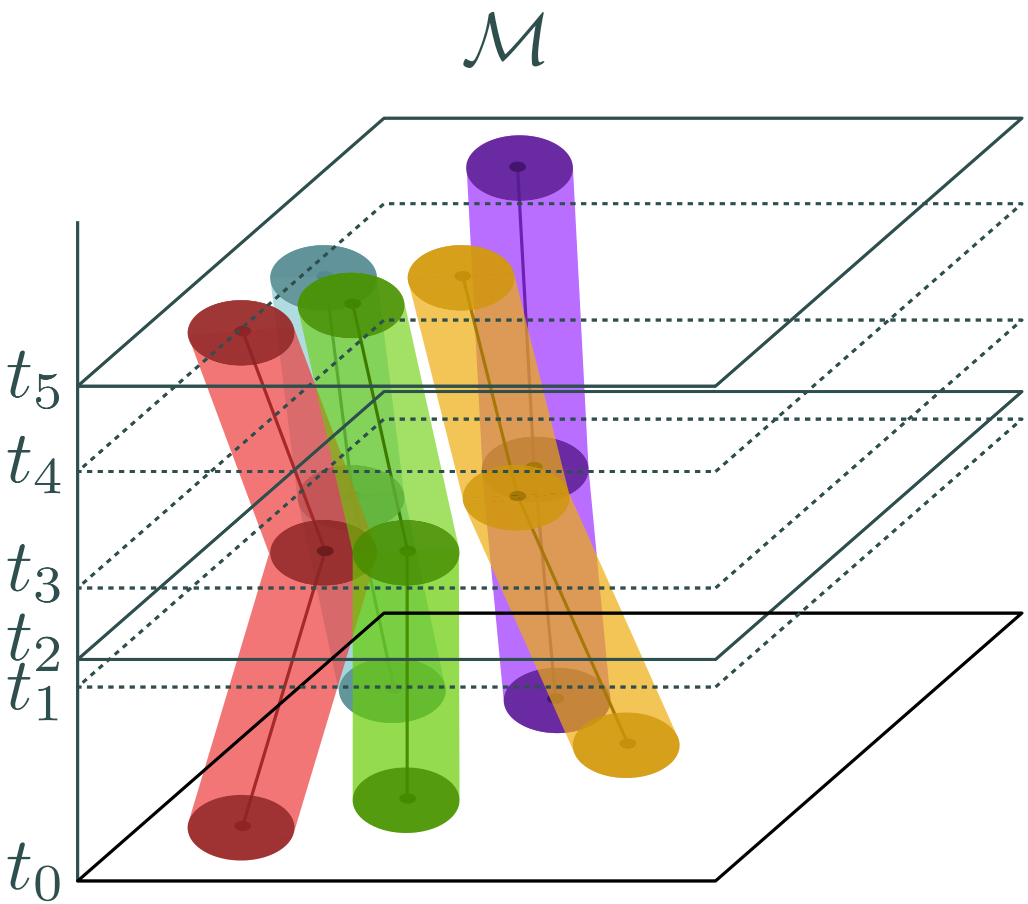
Groups change when connectivity in $\mathcal{M}$ changes.



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Each entity produces a "tube". Let $\mathcal{M}$ be the union of those n "tubes".

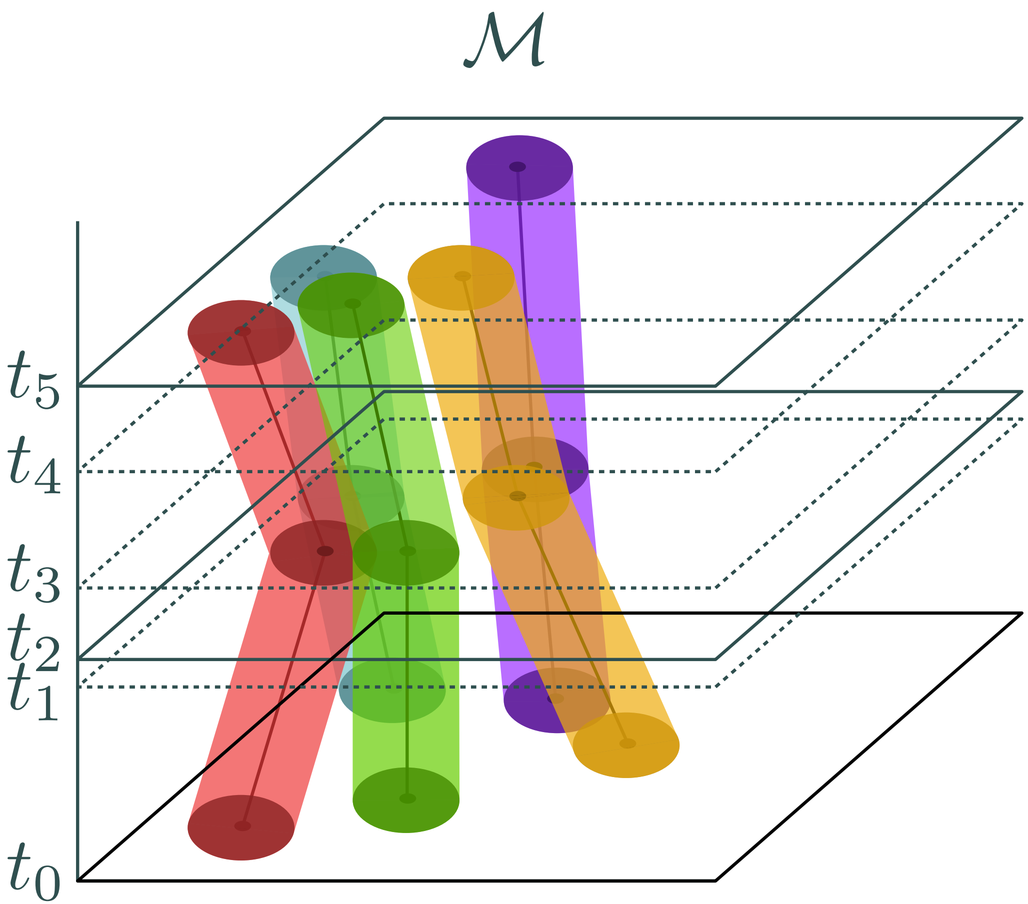
Groups change when connectivity in $\mathcal{M}$ changes.

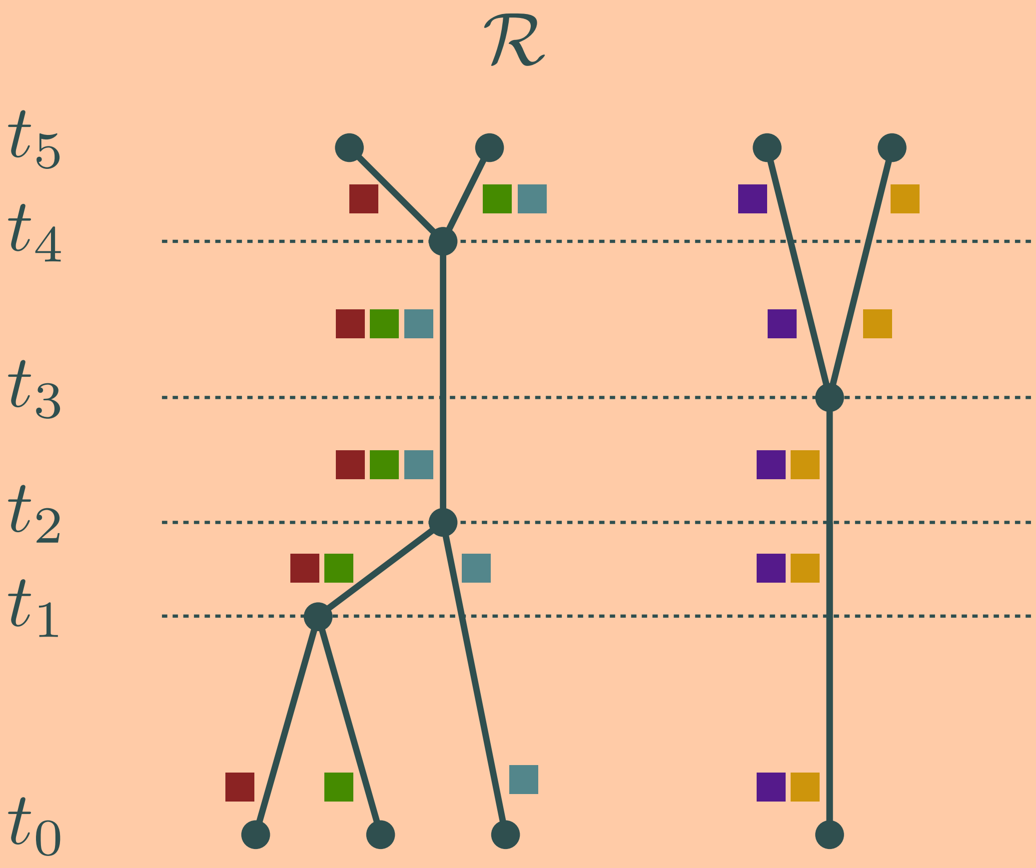
The Reeb graph $\mathcal{R}$ of $\mathcal{M}$ captures connectivity changes.

$\Longrightarrow$

Reeb graph captures all group changes.

The Reeb Graph



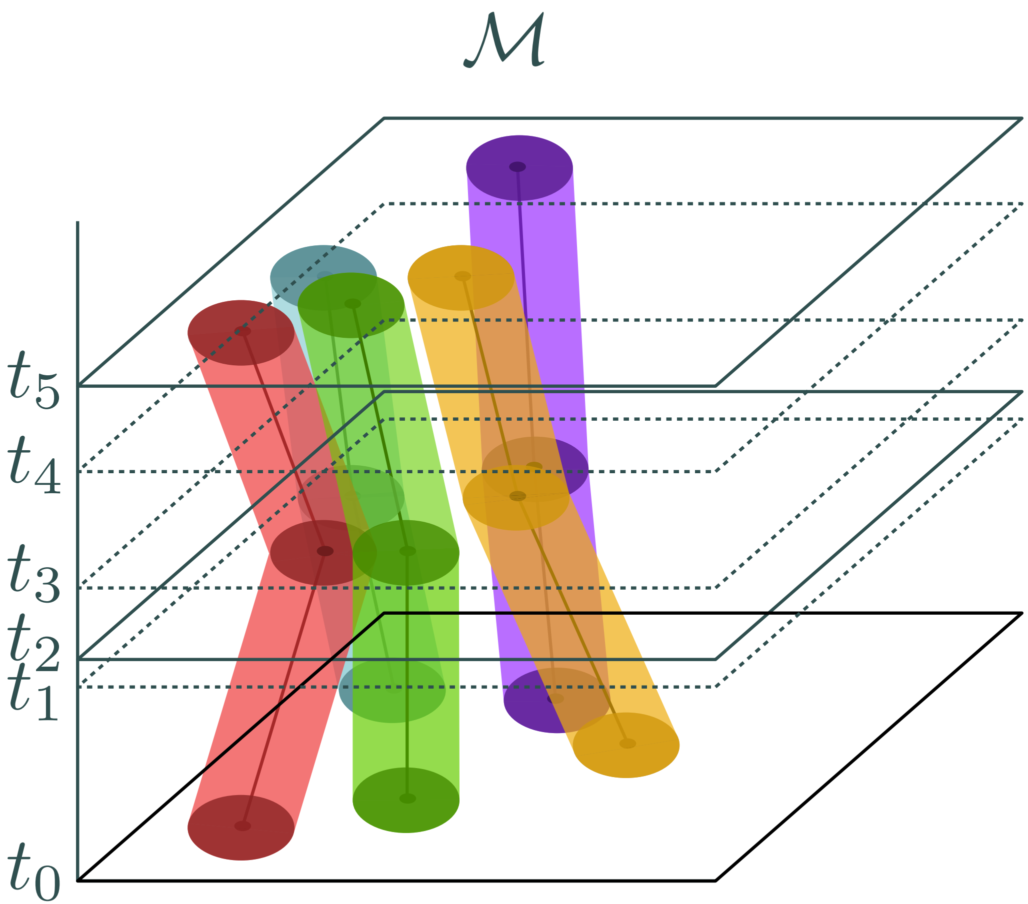


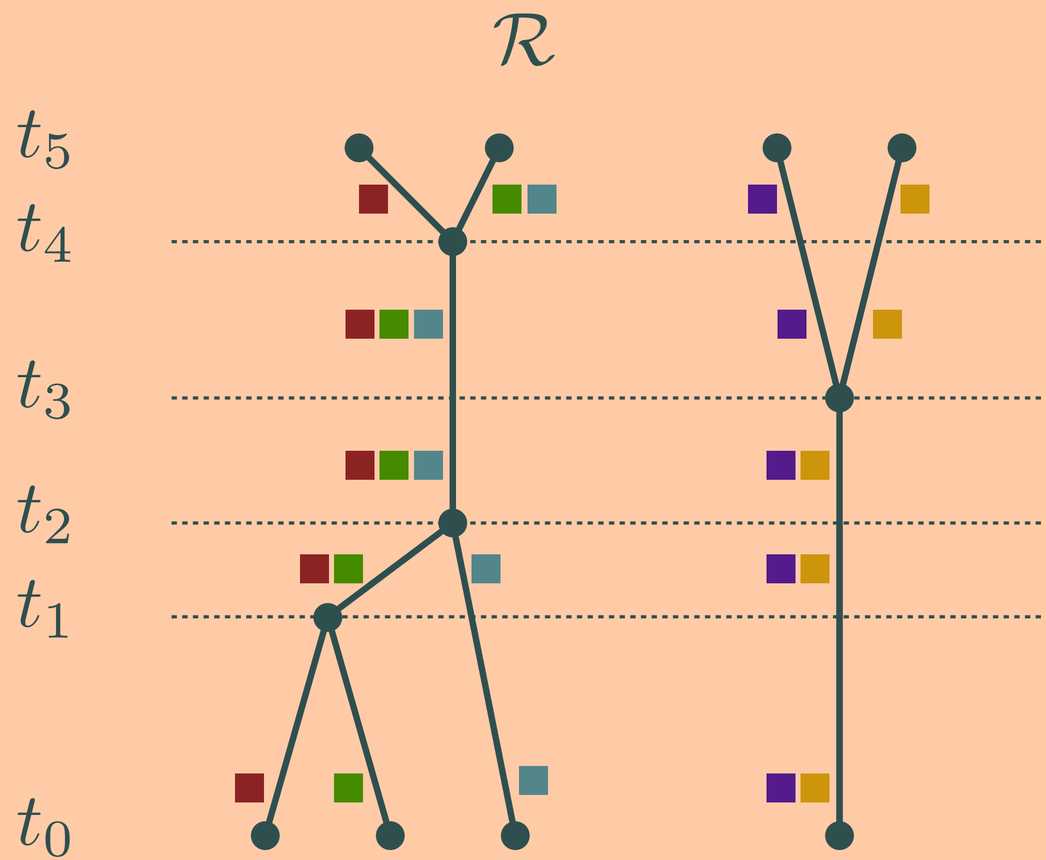
The Reeb Graph

Annotate $\mathcal{R}$ with all groups

$\Longrightarrow$

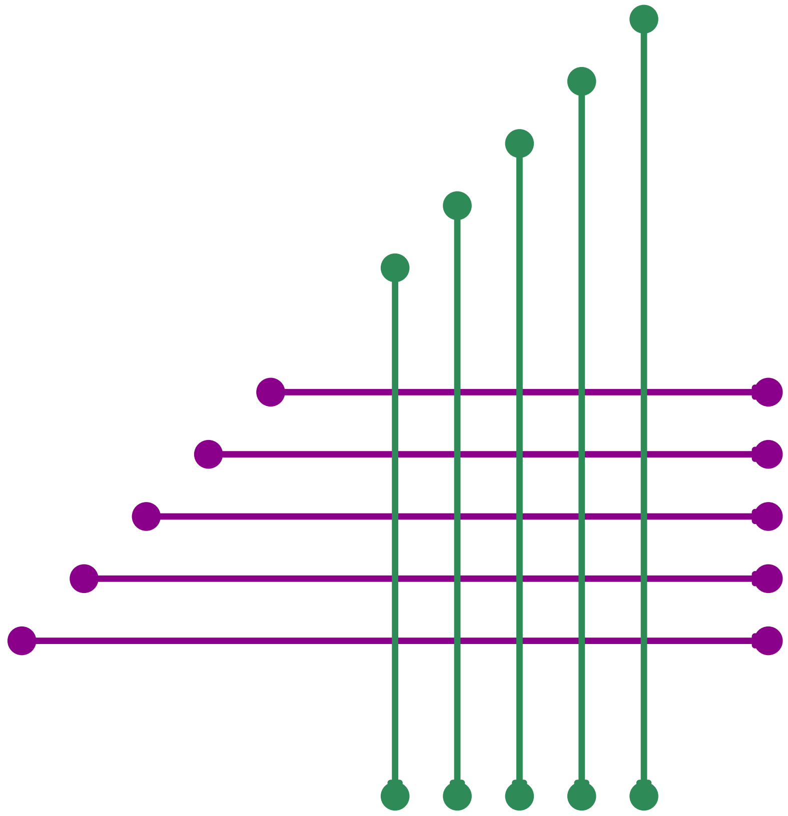
Trajectory Grouping Structure





The Reeb Graph

Complexity $\mathcal{R}$?

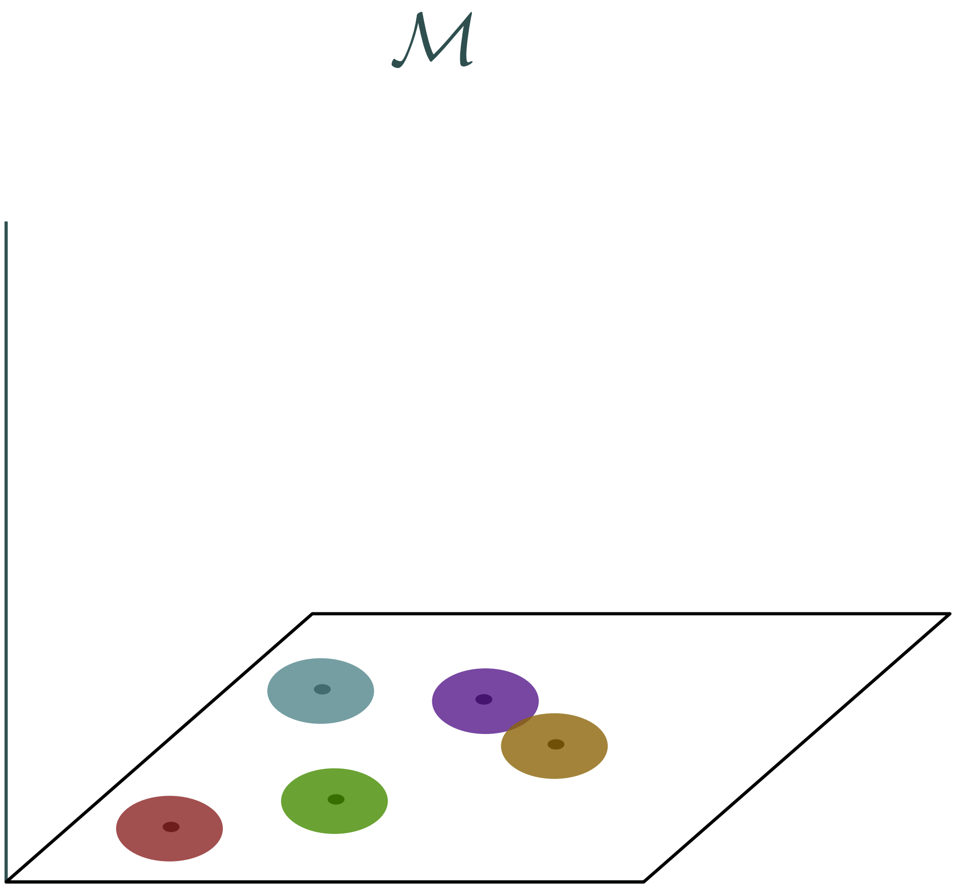


The Reeb Graph

Complexity $\mathcal{R}$?

$\Theta(\tau n^2)$

$\tau =$ trajectory length



The Reeb Graph

How to compute $\mathcal{R}$?

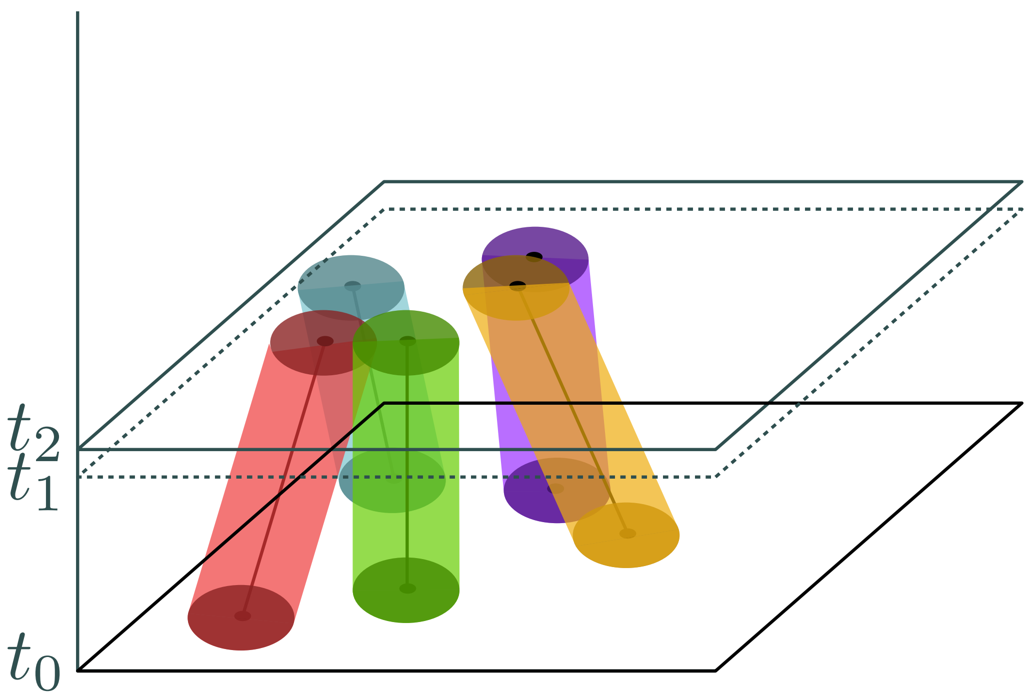
Sweep $\mathcal{M}$ while maintaining connected components.

The Reeb Graph

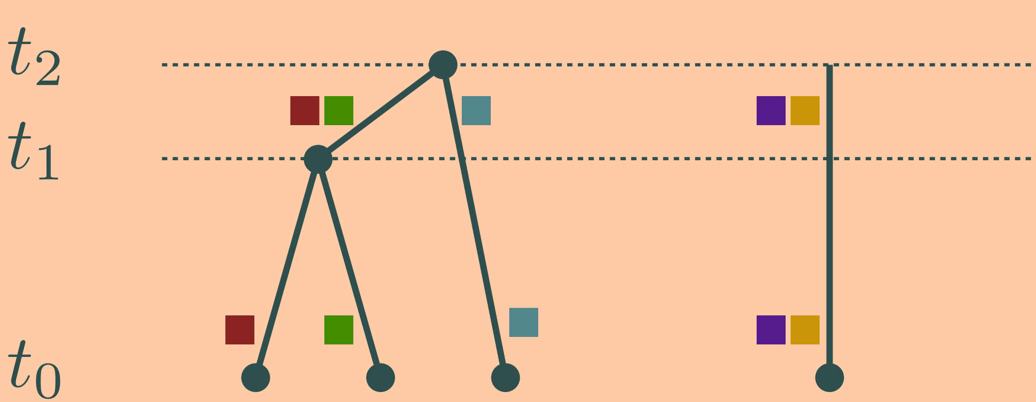
How to compute $\mathcal{R}$?

Sweep $\mathcal{M}$ while maintaining connected components.

$\mathcal{M}$



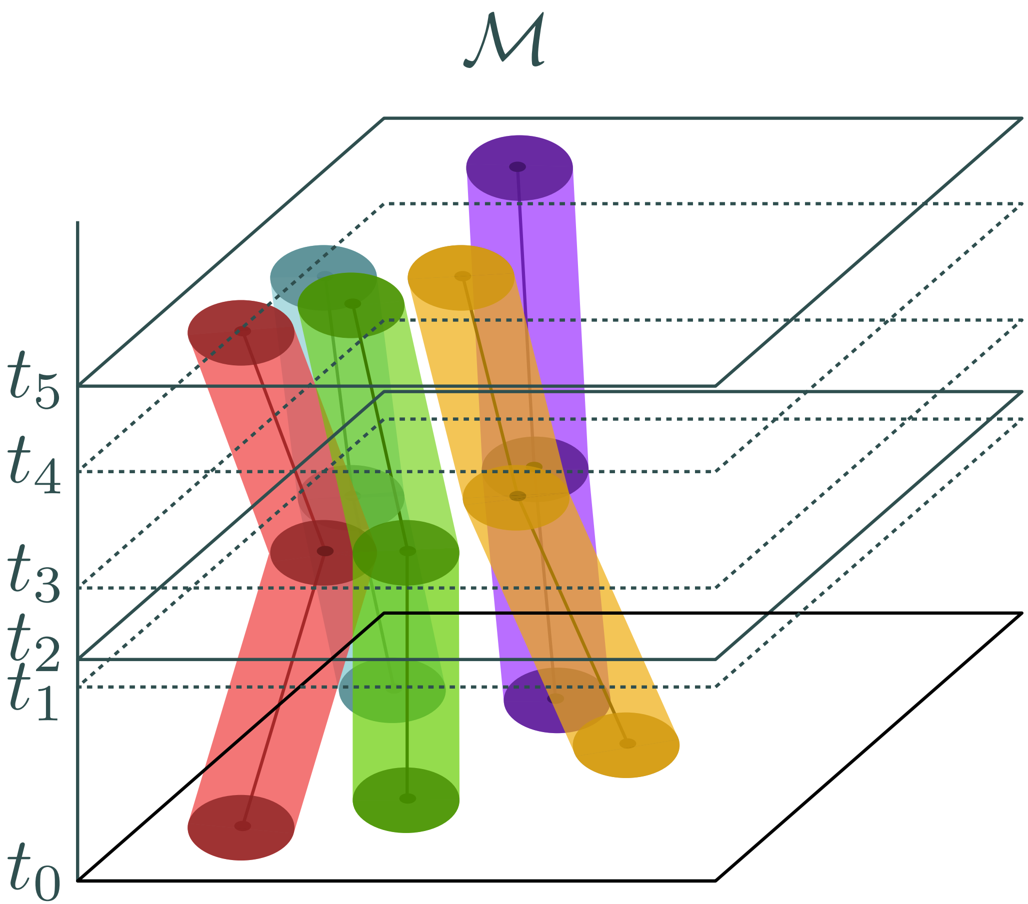
$\mathcal{R}$

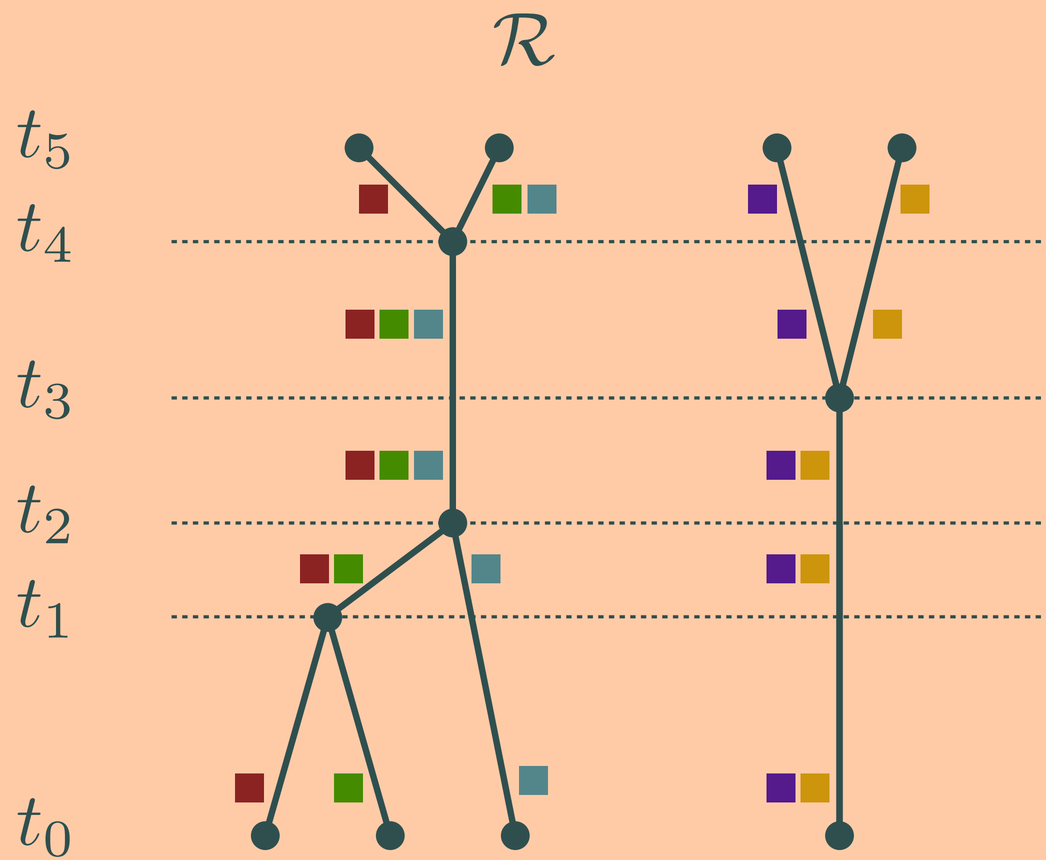


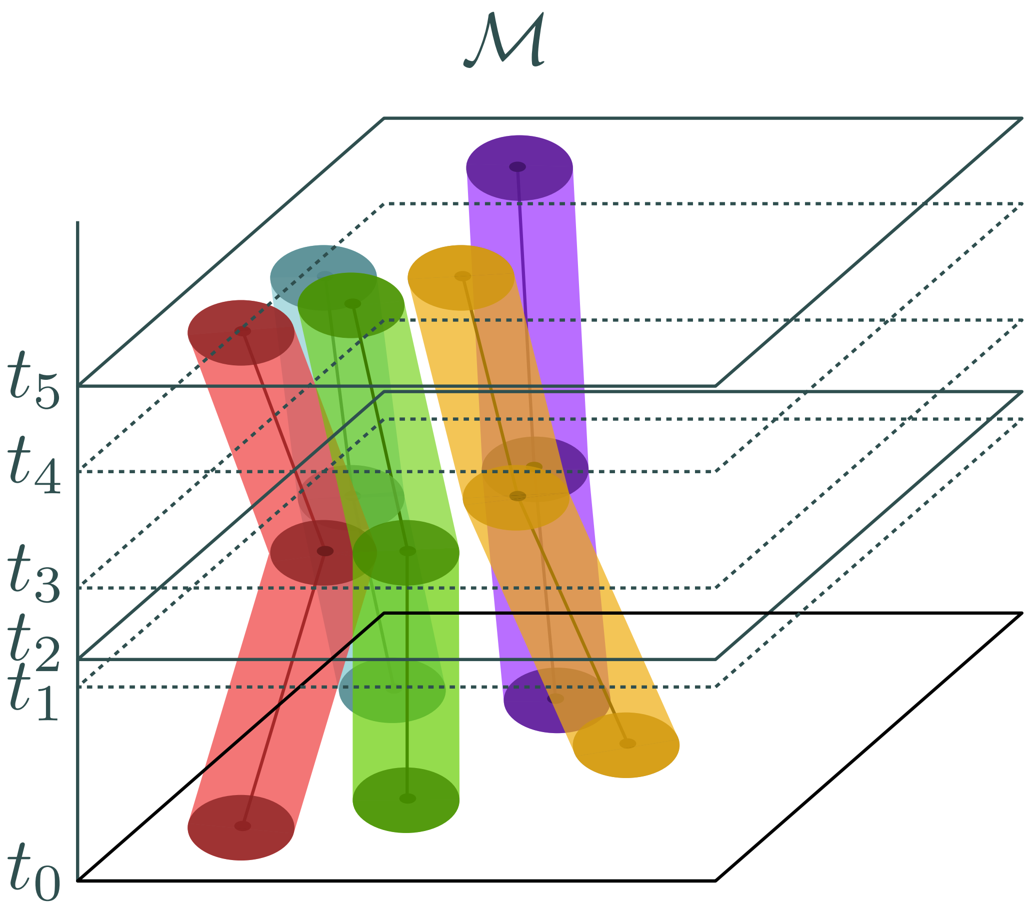
The Reeb Graph

How to compute $\mathcal{R}$?

Sweep $\mathcal{M}$ while maintaining connected components.







The Reeb Graph

How to compute $\mathcal{R}$?

Sweep $\mathcal{M}$ while maintaining connected components.

Running time?

Compute & Sort all events:

$O(\tau n^2 \log n)$ time

Initialize graph:

$O(n^2)$ time

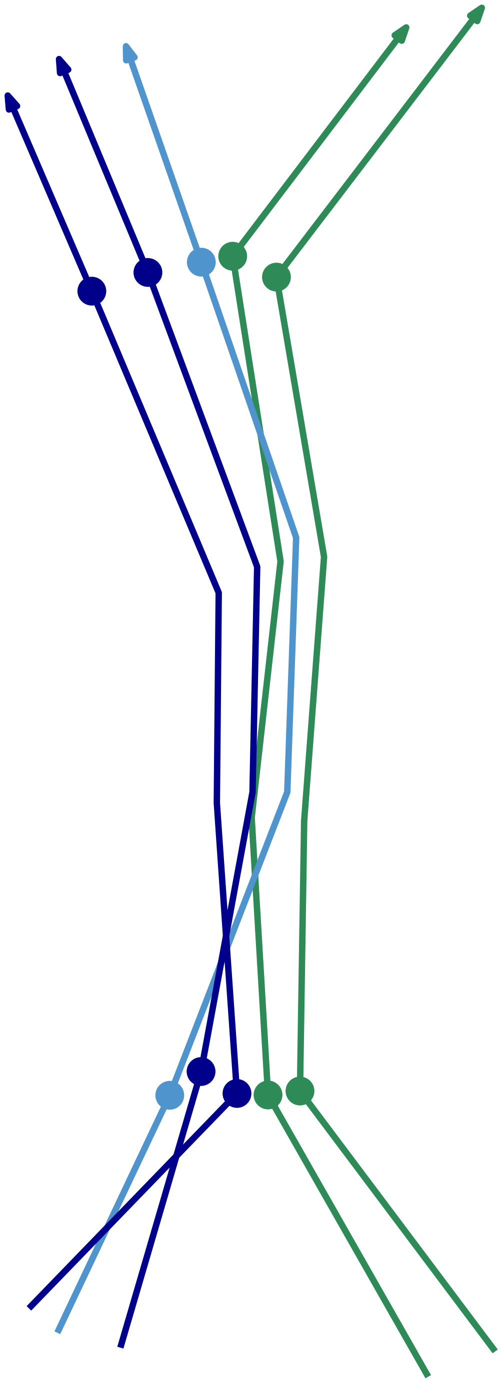
Handle an event:

$O(\log n)$ time

Total: $O(\tau n^2 \log n)$ time

Computing all Groups

How many groups?



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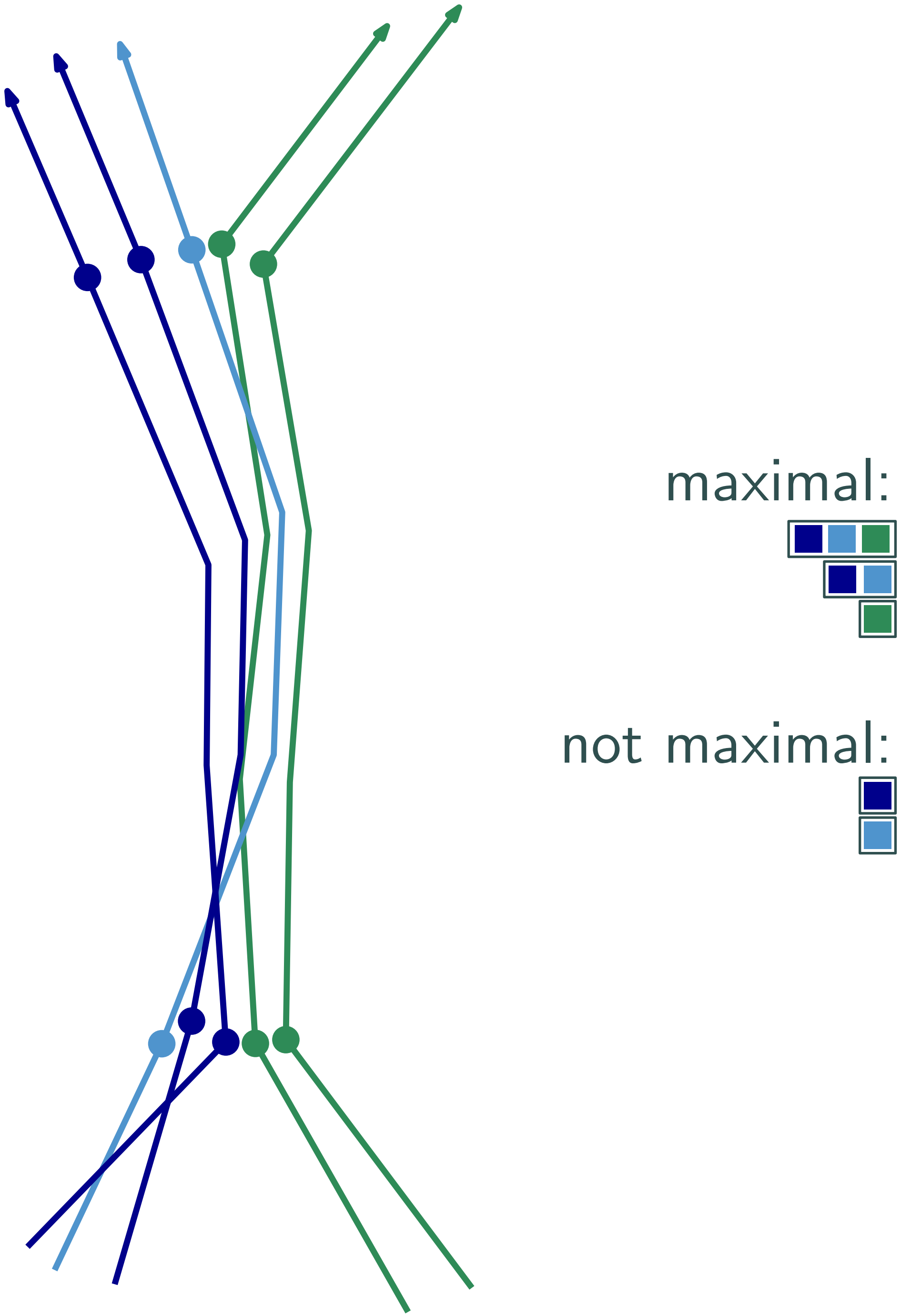
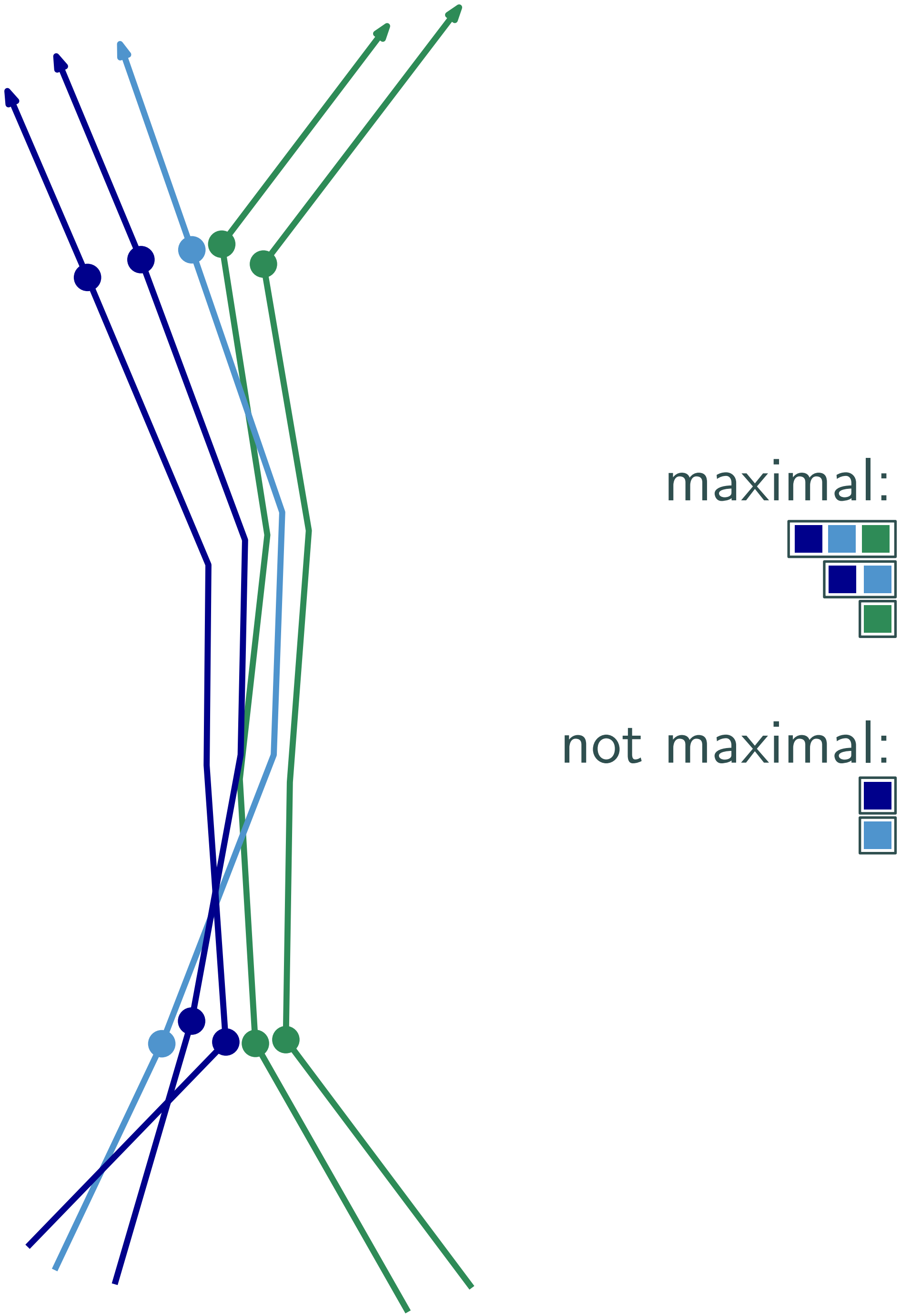


How many maximal groups?



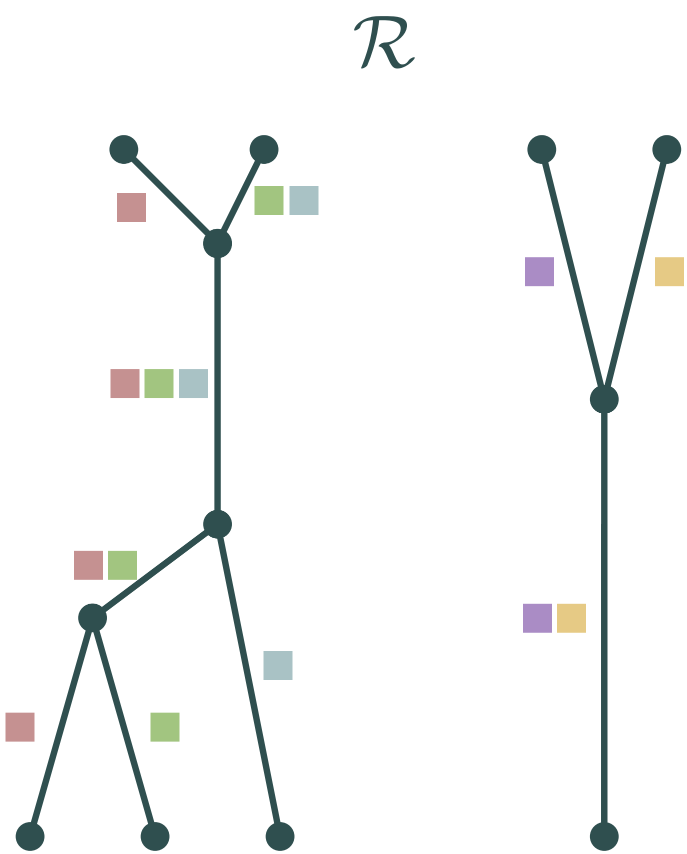
Computing all Groups

How many maximal groups?

At most n per vertex

$\implies \Theta(\tau n^3)$ in total.

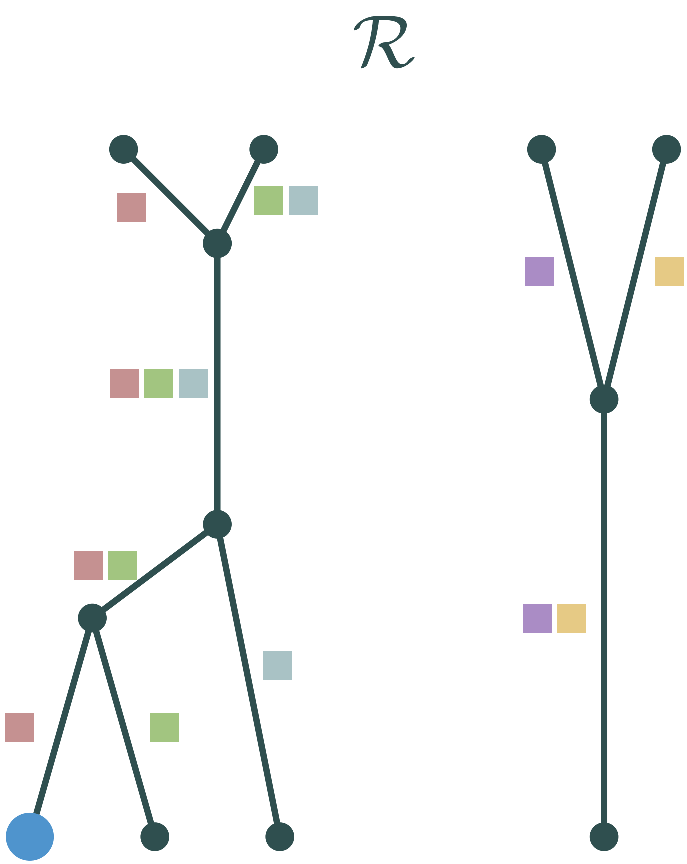
Computing all Groups



How to compute all maximal groups?

with parameters ε, m, and δ

1. Compute $\mathcal{R}$ for the given ε.
2. Process the vertices in time order.
3. Label the outgoing edges with all known maximal groups, assuming $m = 1$ and $\delta = 0$.
4. Filter the groups on δ and m.



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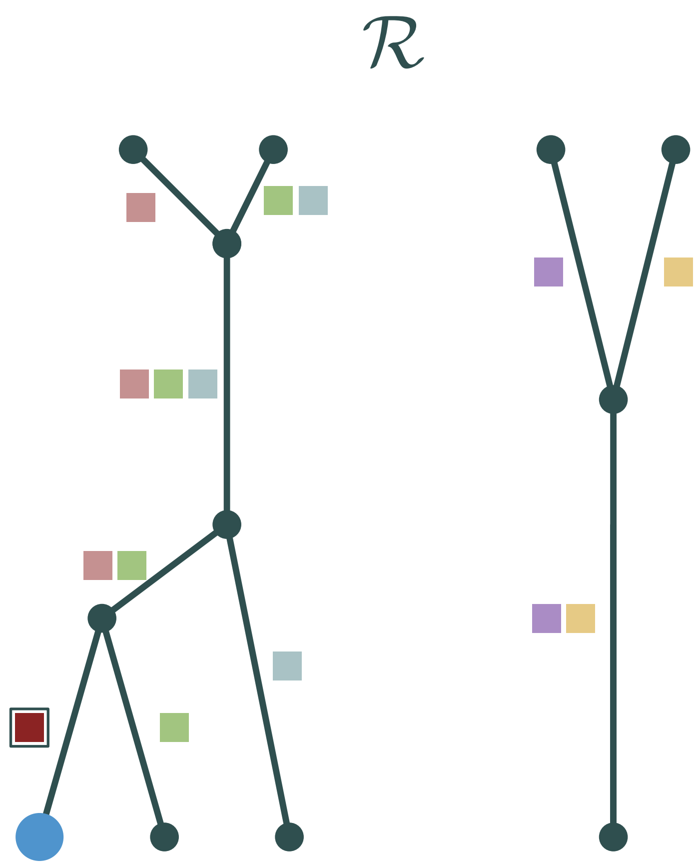

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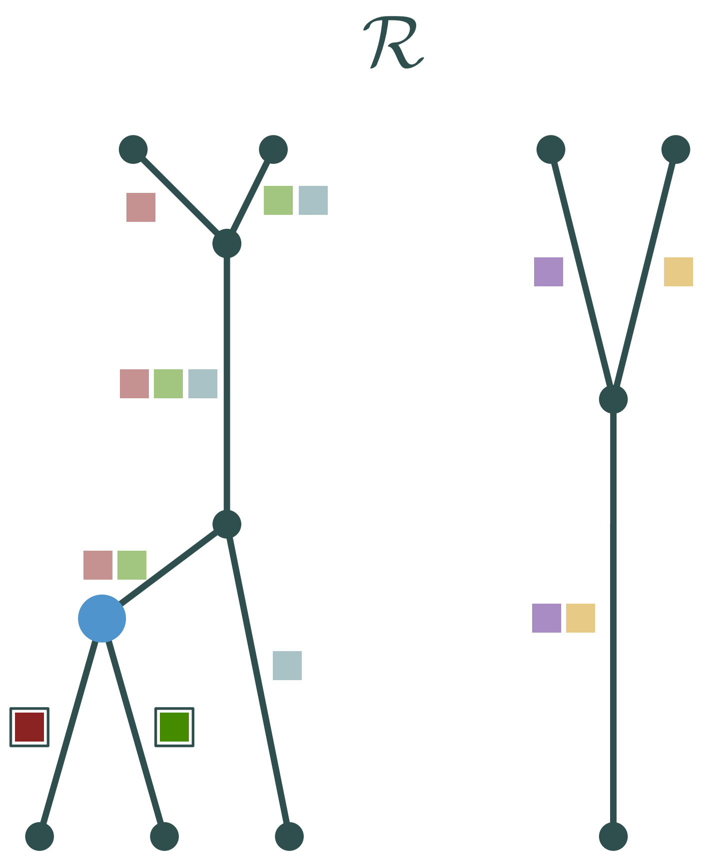

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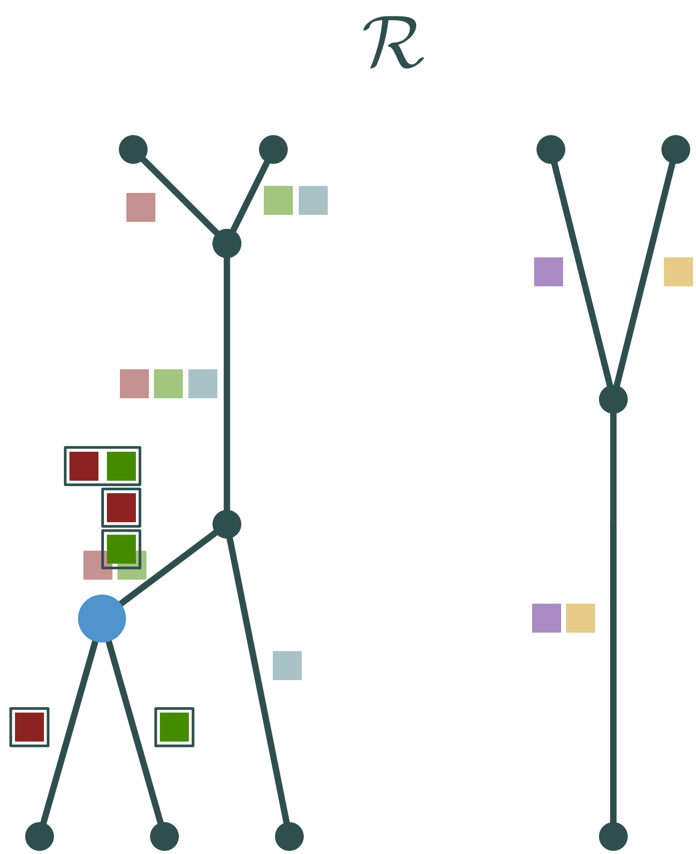

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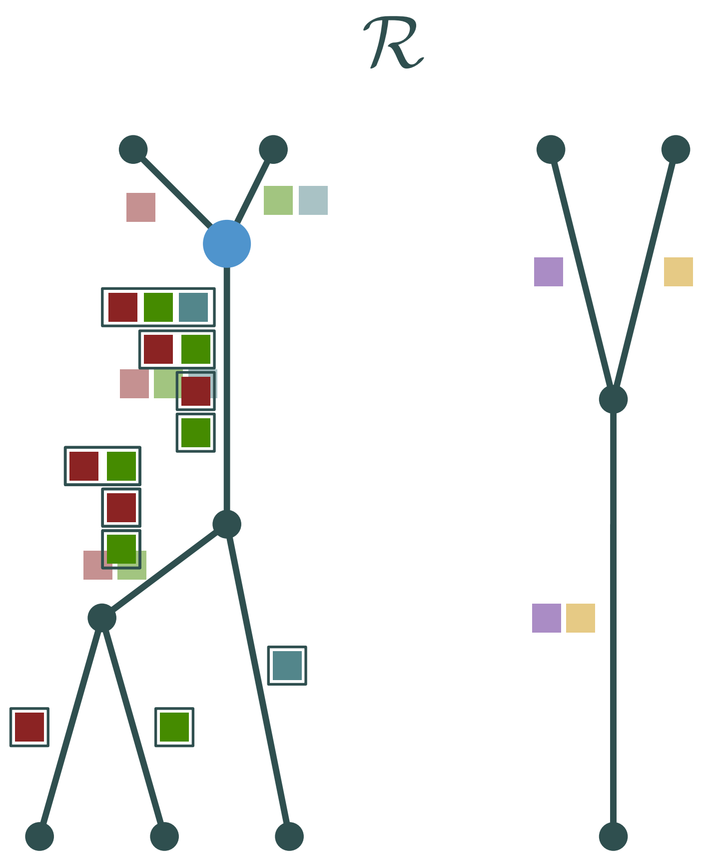

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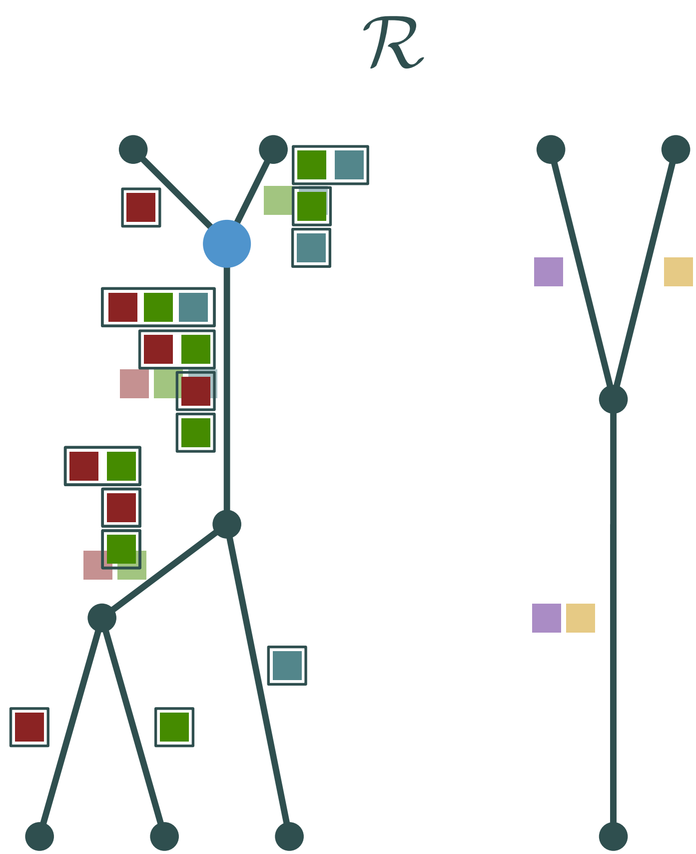

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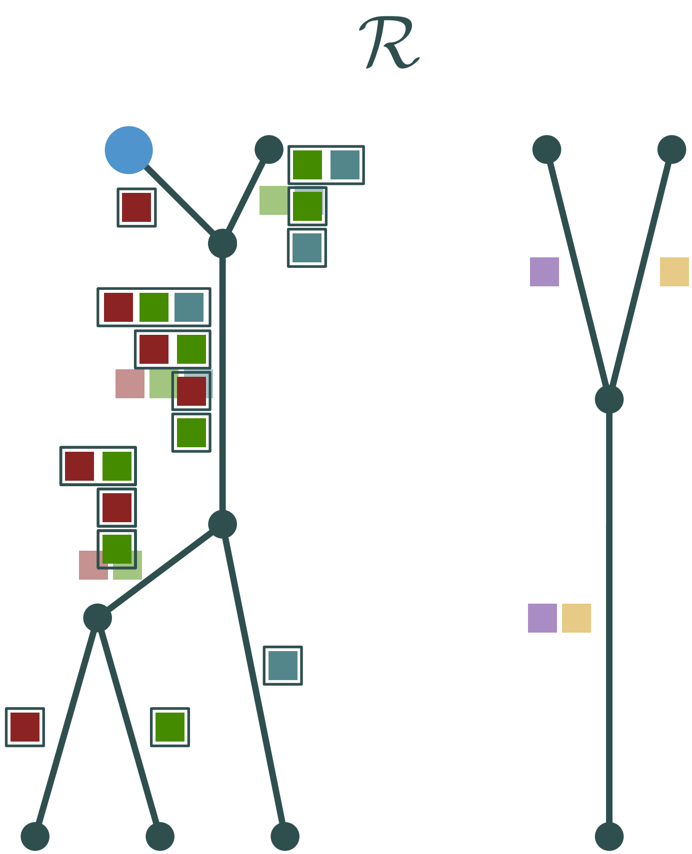

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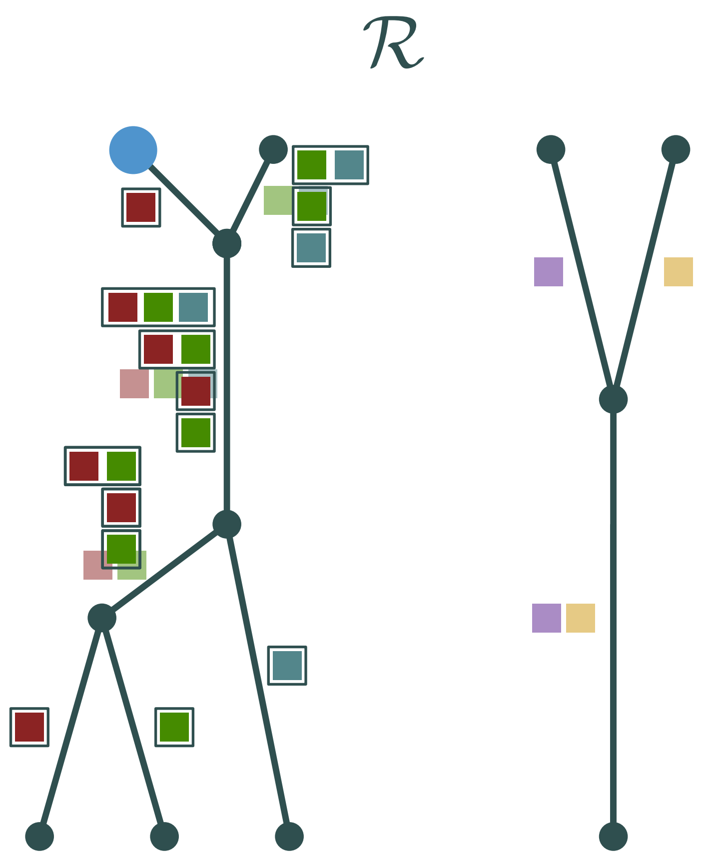

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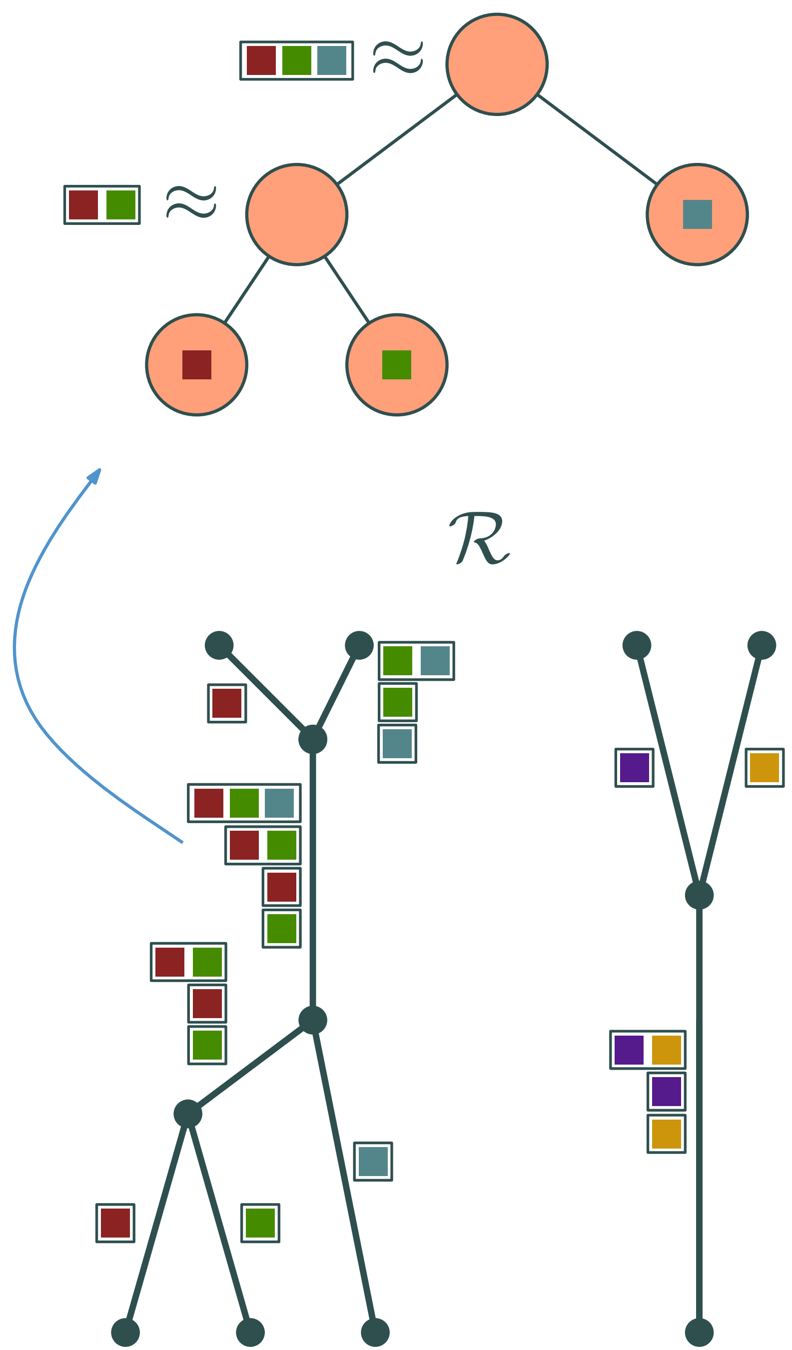

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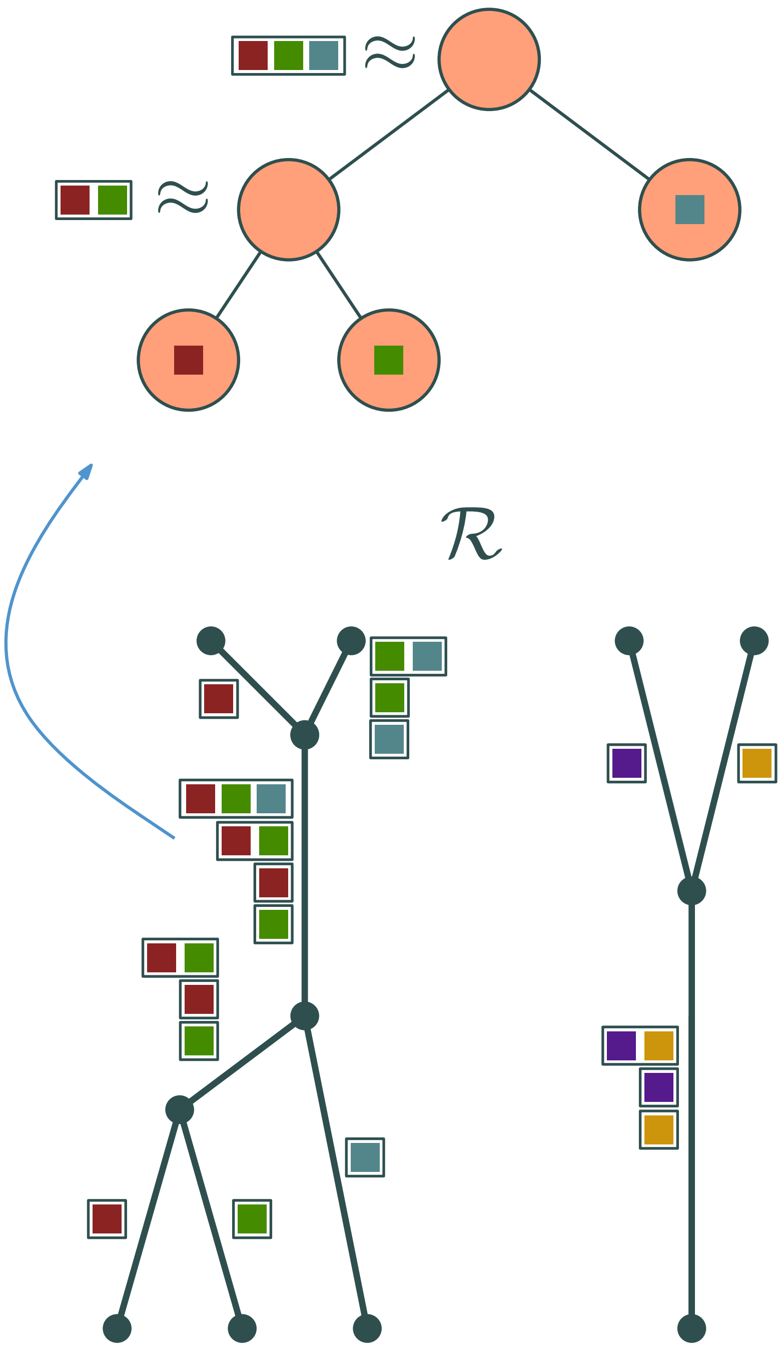
How to represent the groups?

Use a binary tree.



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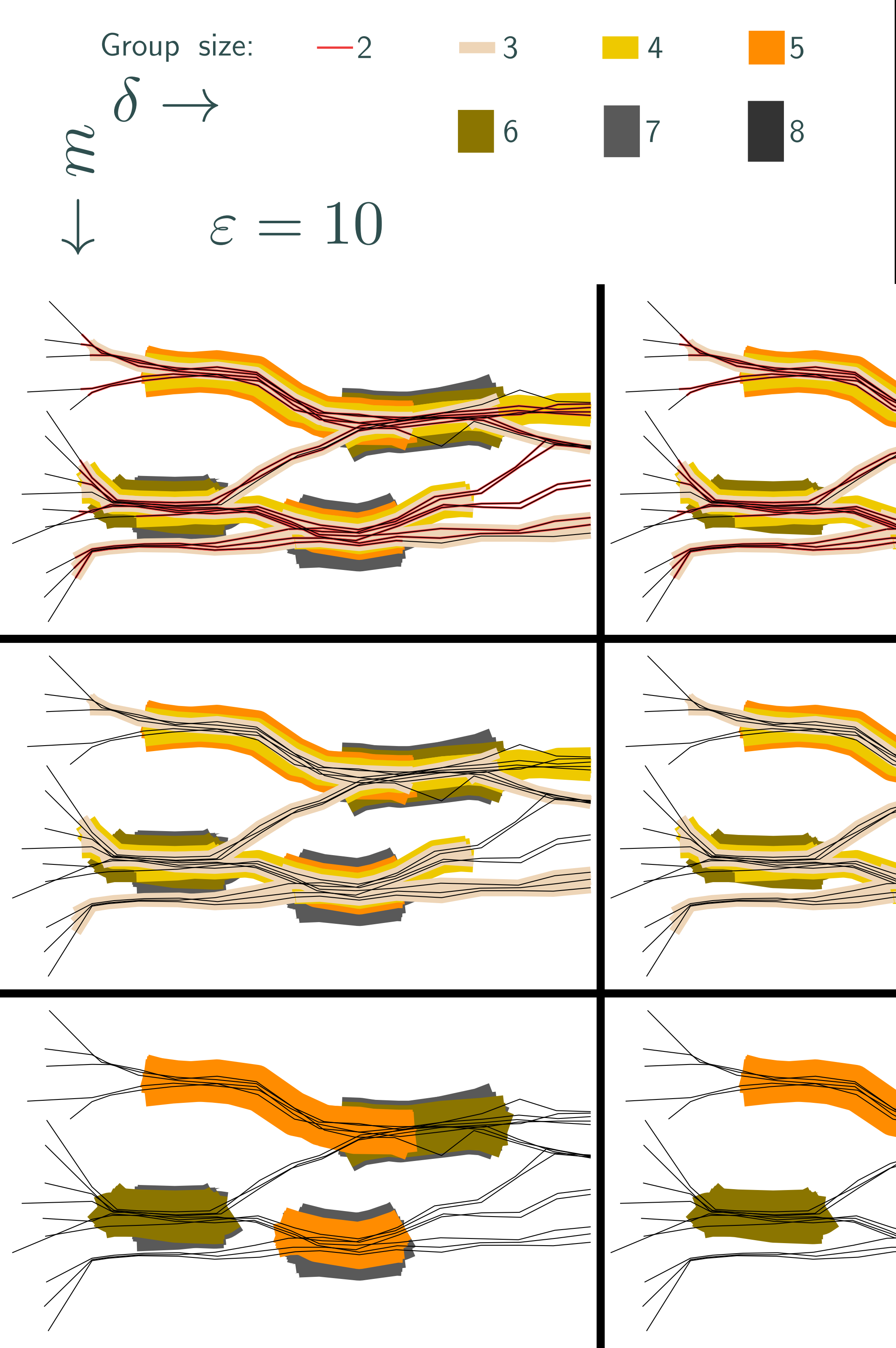
How to represent the groups?

Use a binary tree.

Running time: $O(\tau n^3 + N)$.

N = total group size

Different Scales



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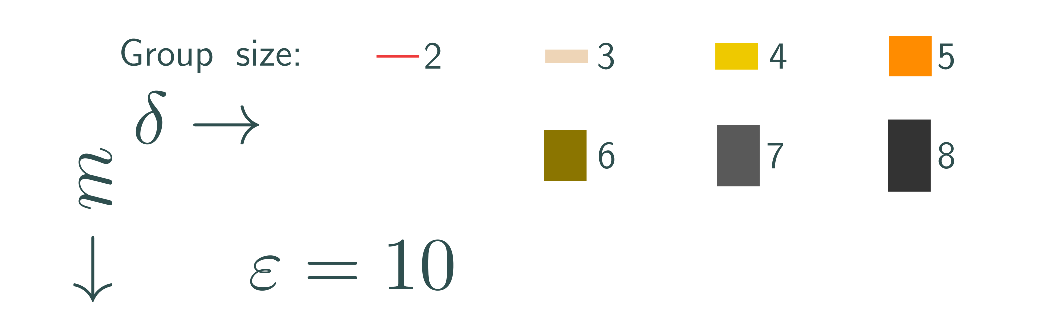

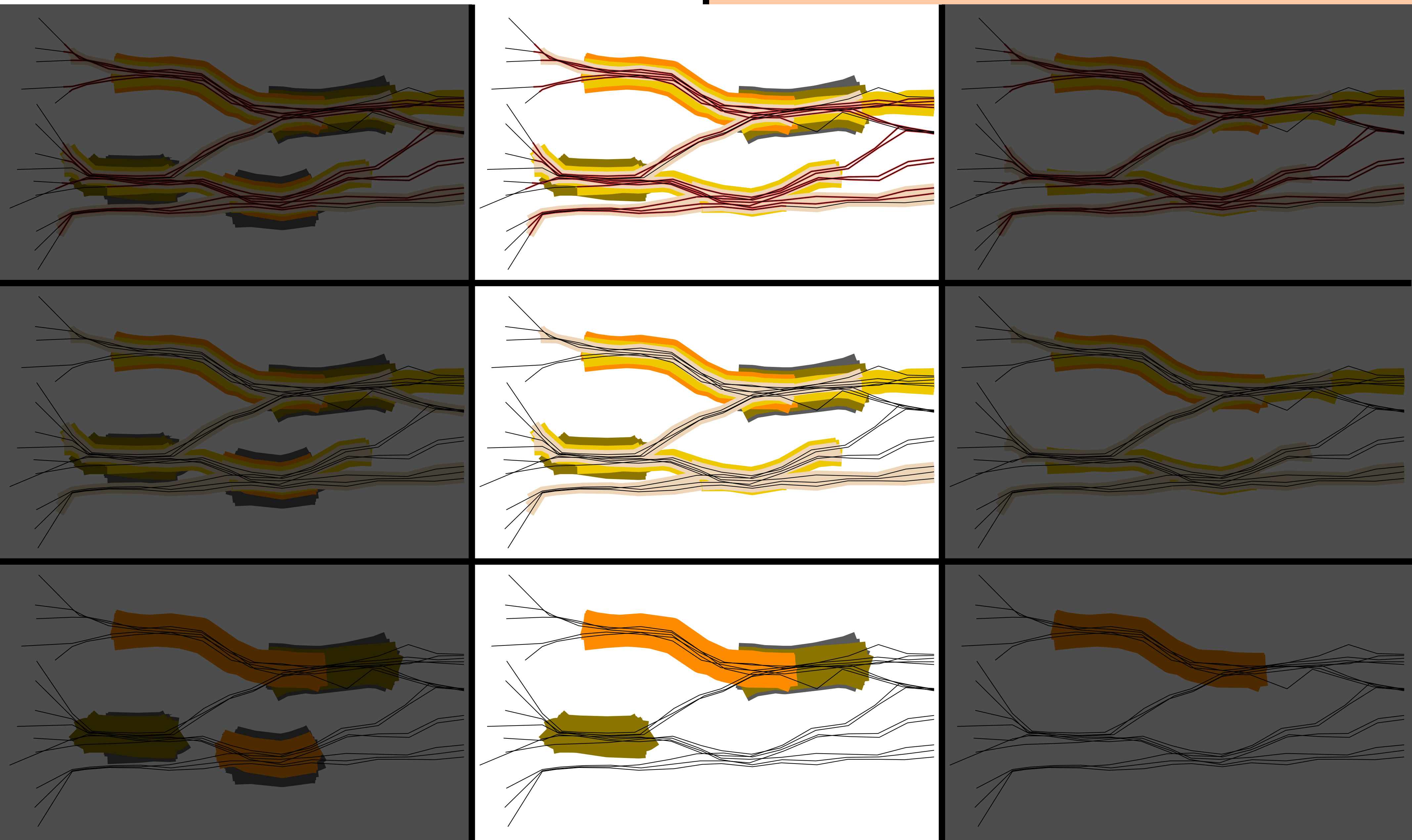

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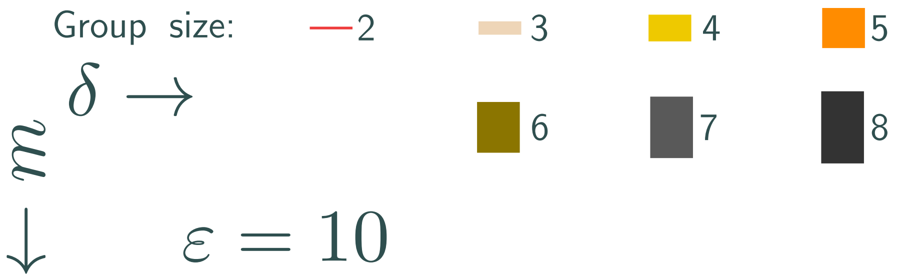
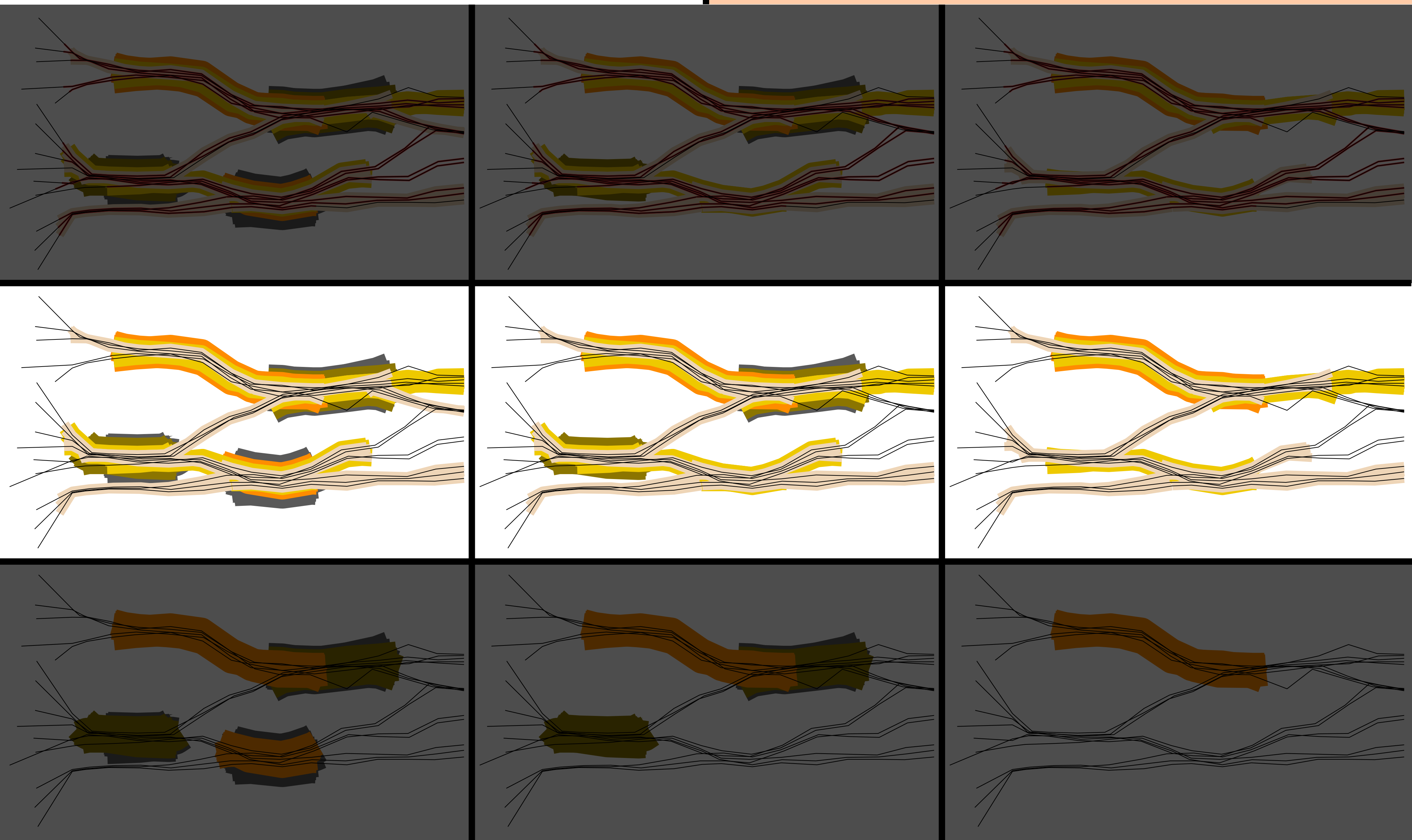




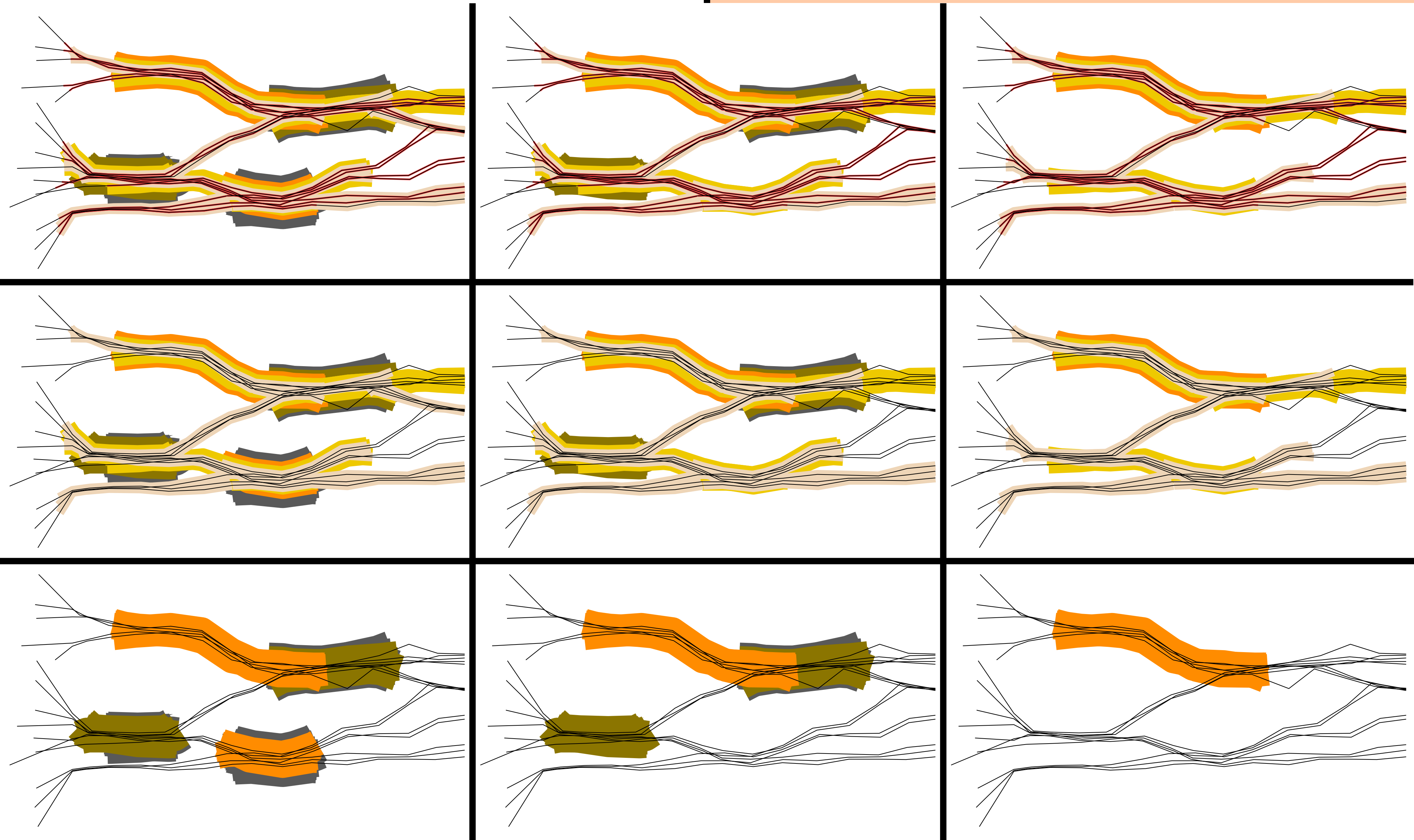
Different Scales

Group size: 2 3 4 5 6 7 8

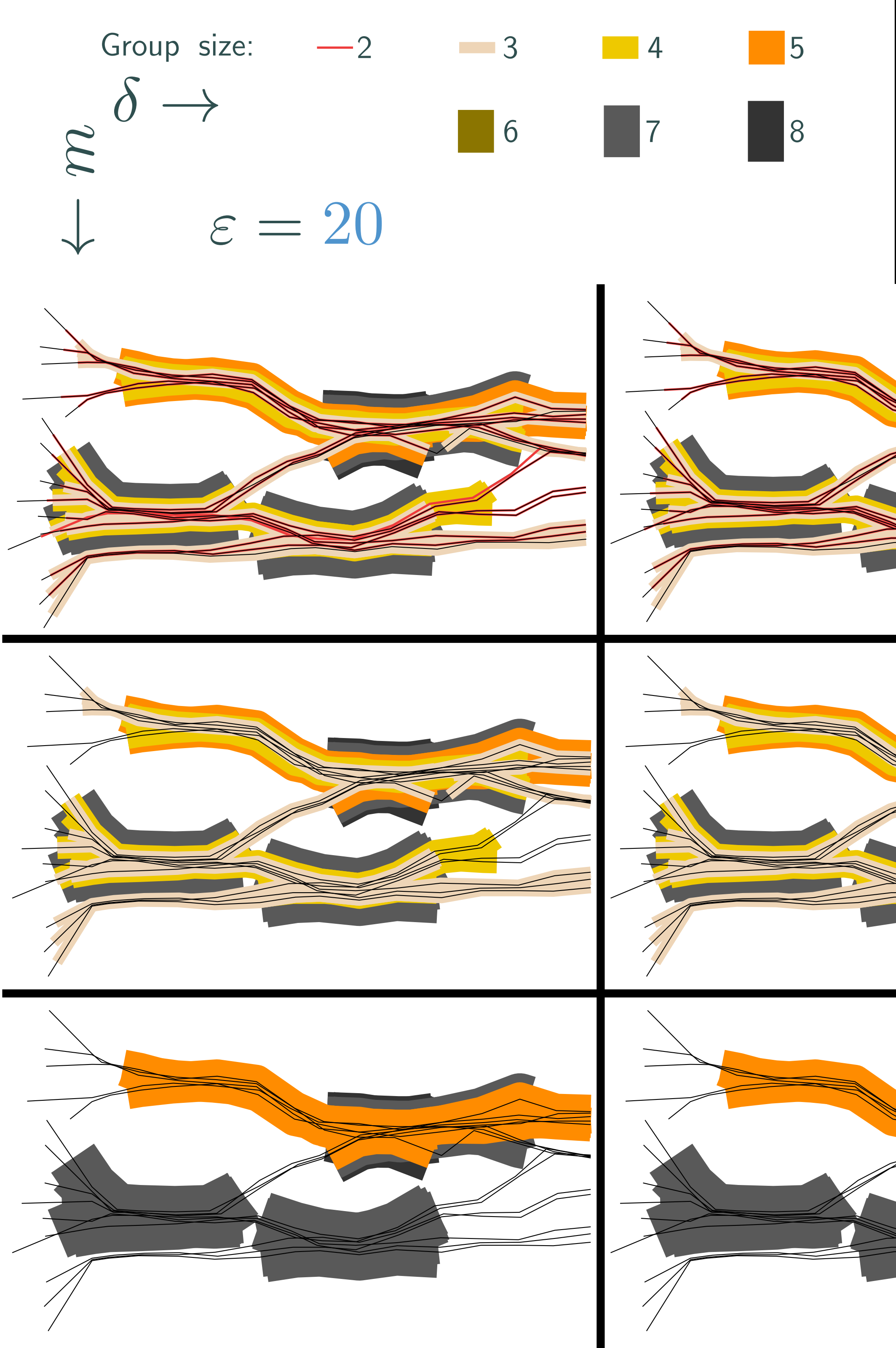
$\delta \rightarrow$

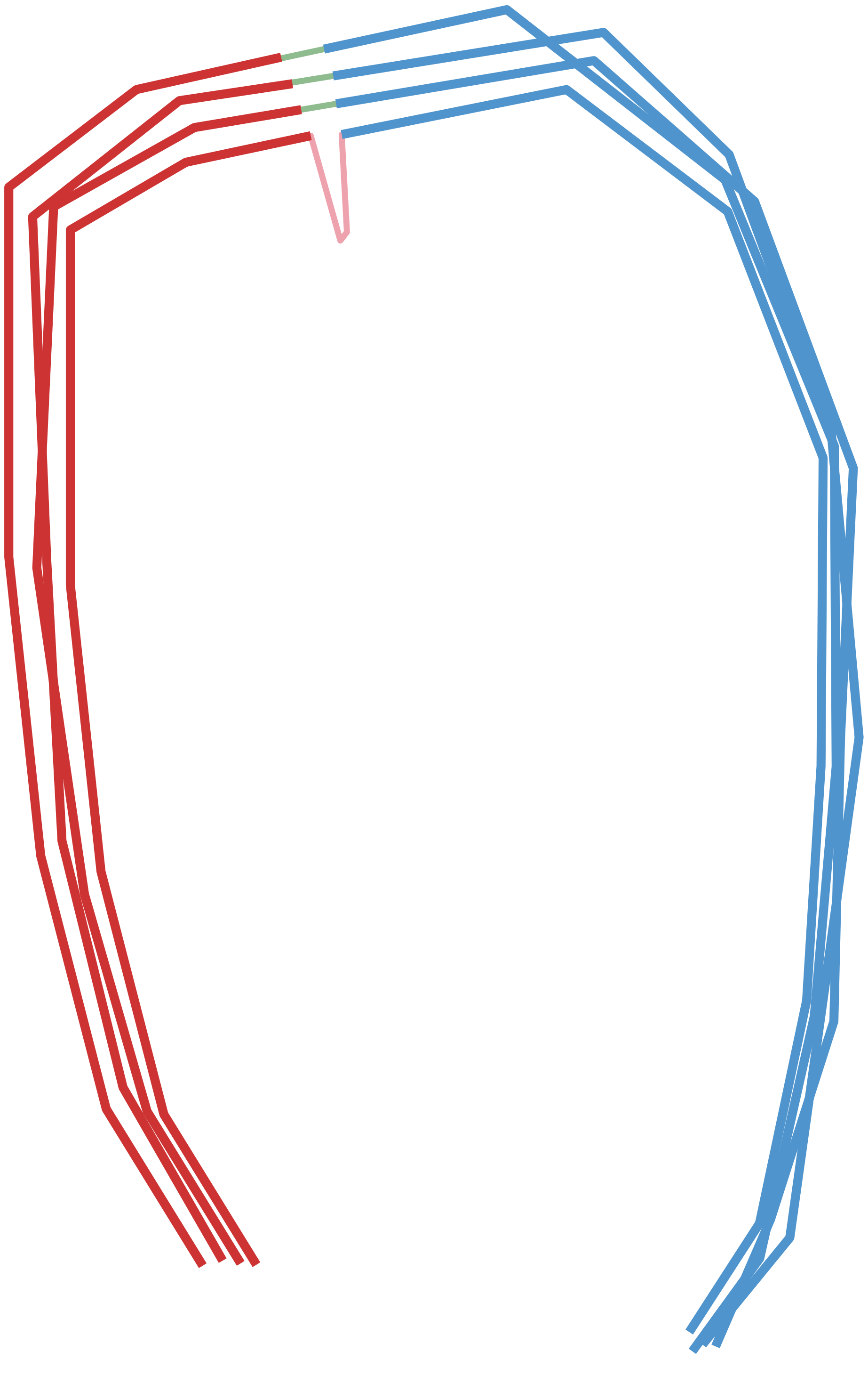
$m \downarrow$

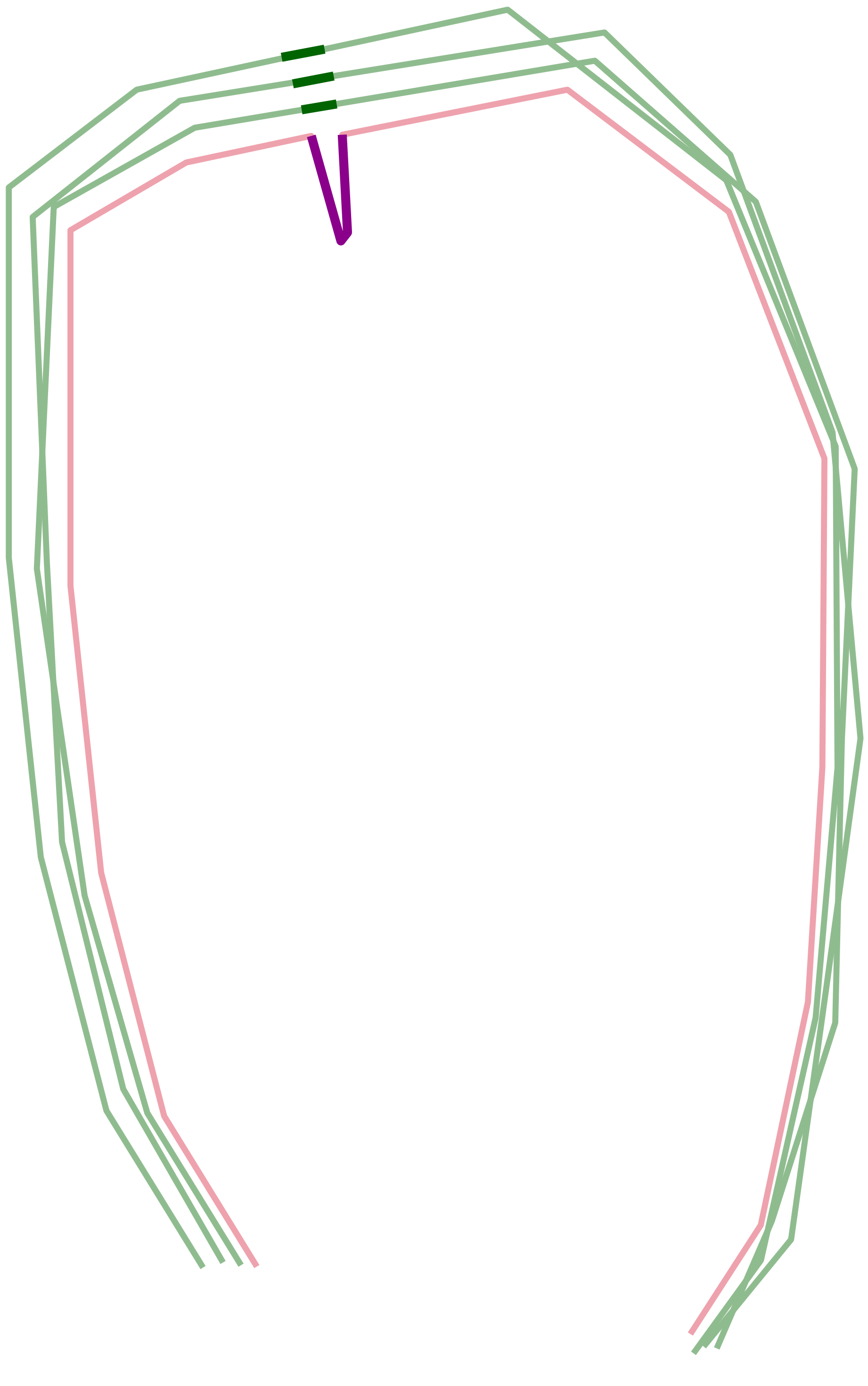
$\varepsilon = 10$

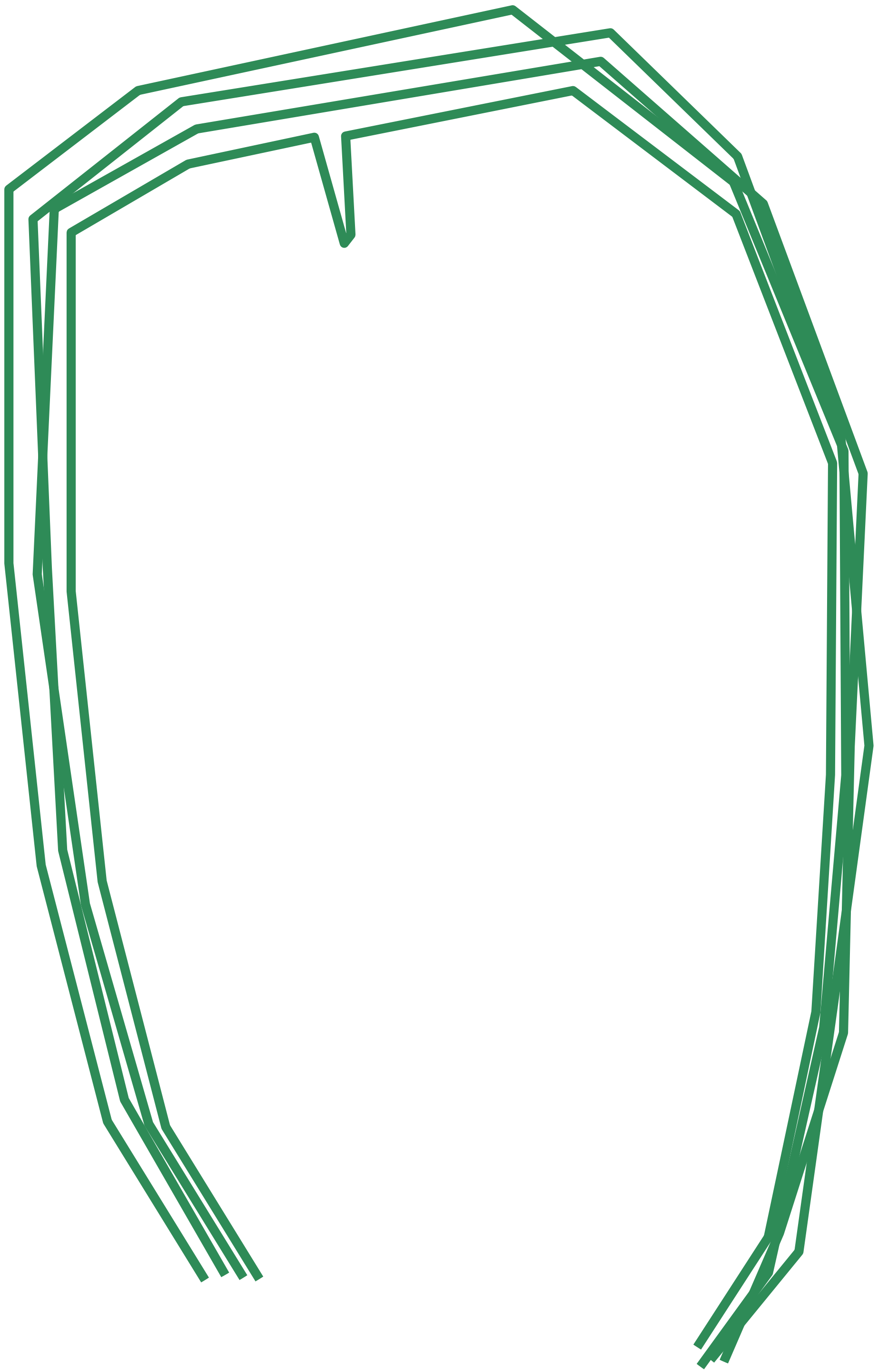


Different Scales

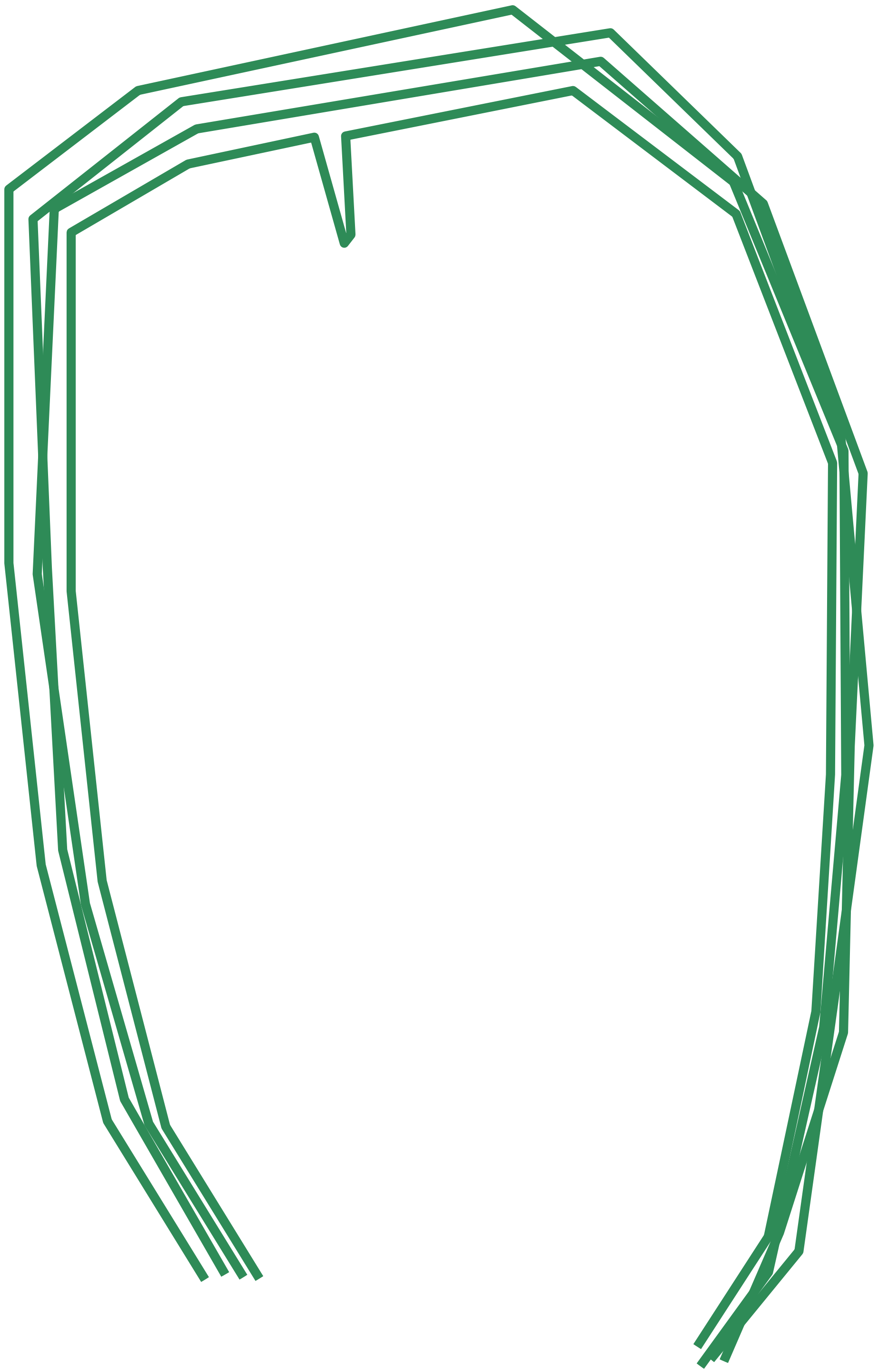








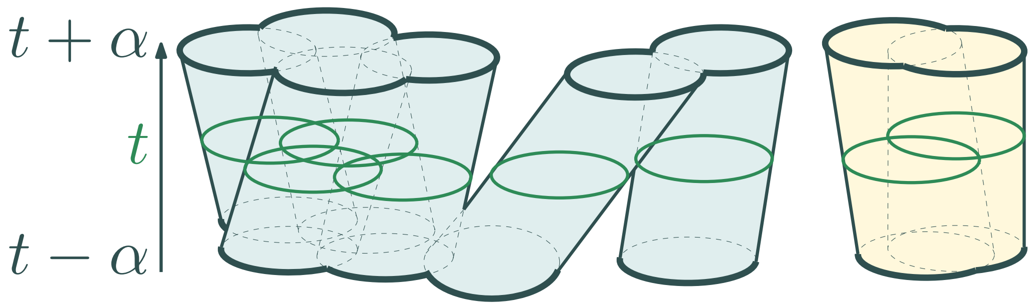
Robustness



Robustness

Introduce a new parameter α

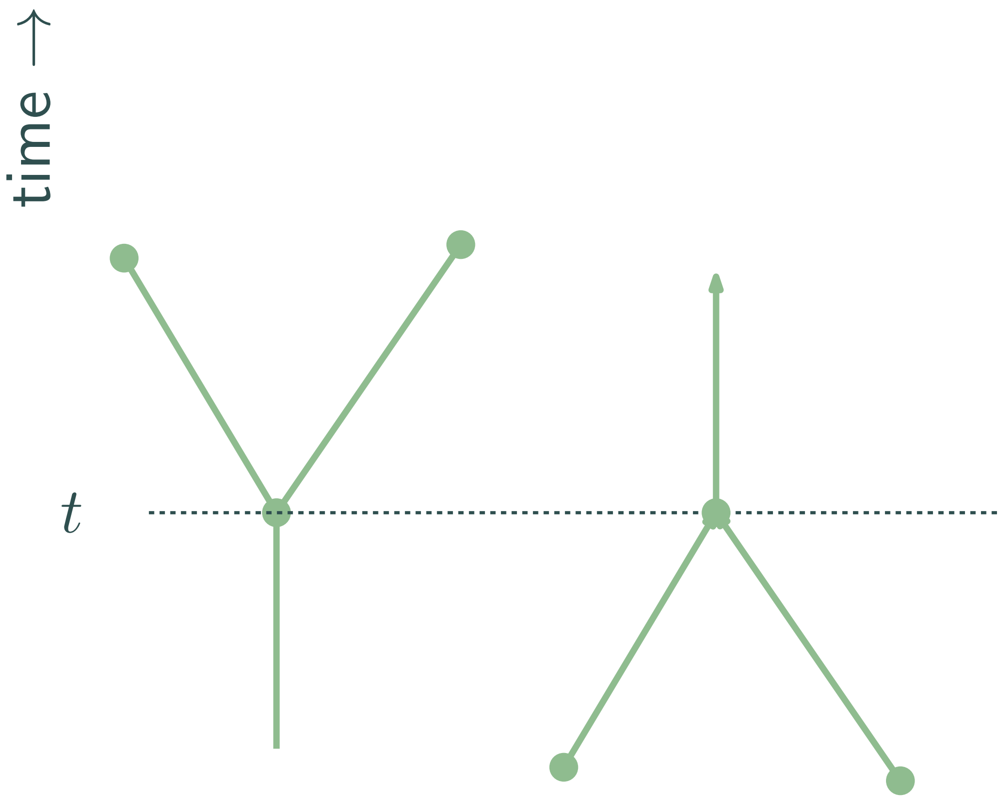
x and y are in one group at time t if they are ε-connected at a time $t' \in [t-\alpha, t+\alpha]$



Robustness

Introduce a new parameter α

x and y are in one group at time t if they are ε-connected at a time $t' \in [t - \alpha, t + \alpha]$



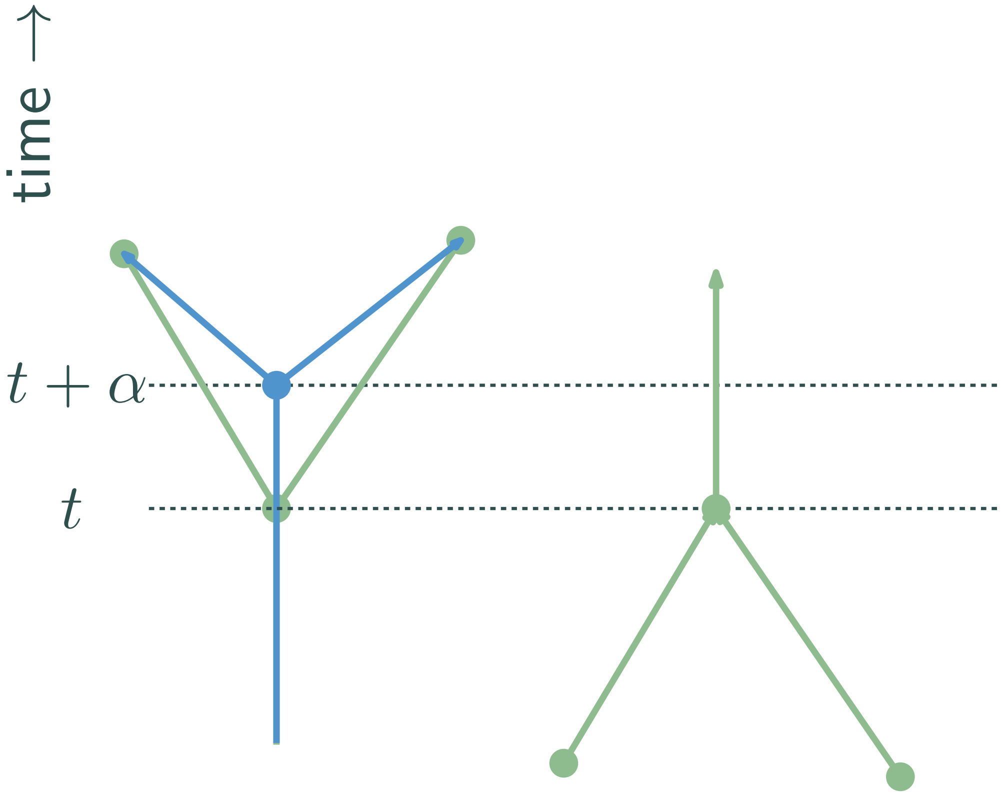
Robustness

Introduce a new parameter α

x and y are in one group at time t if they are ε-connected at a time $t' \in [t - \alpha, t + \alpha]$

$\Longrightarrow$

The vertices in $\mathcal{R}$ move in time.



Robustness

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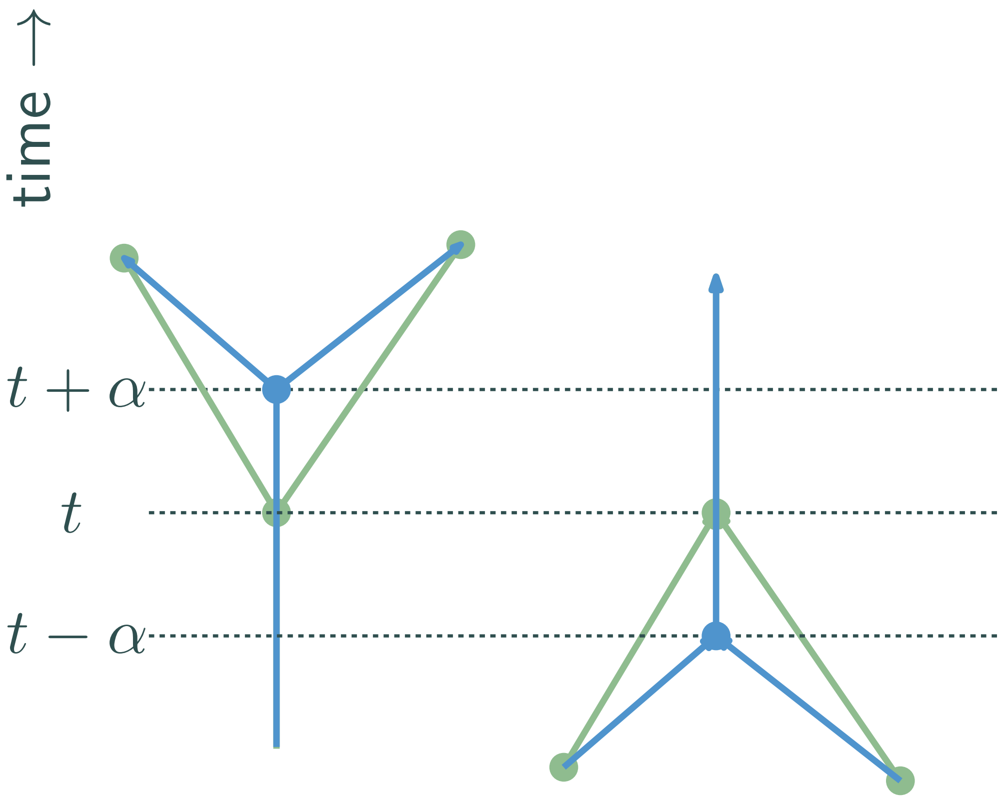


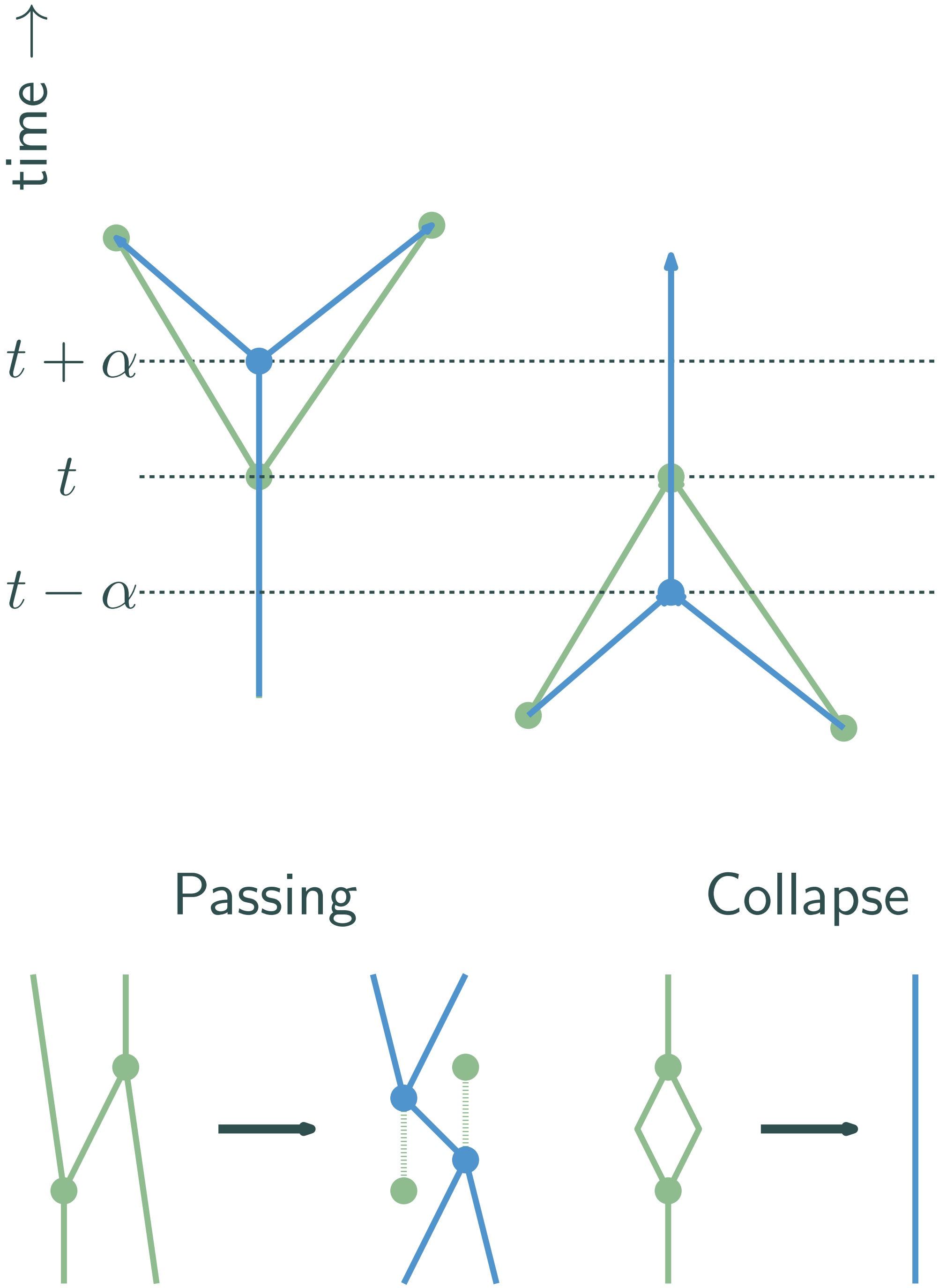
Robustness

Introduce a new parameter α

x and y are in one group at time t if they are ε-connected at a time $t' \in [t-\alpha, t+\alpha]$

$\implies$

The vertices in $\mathcal{R}$ move in time.



Robustness

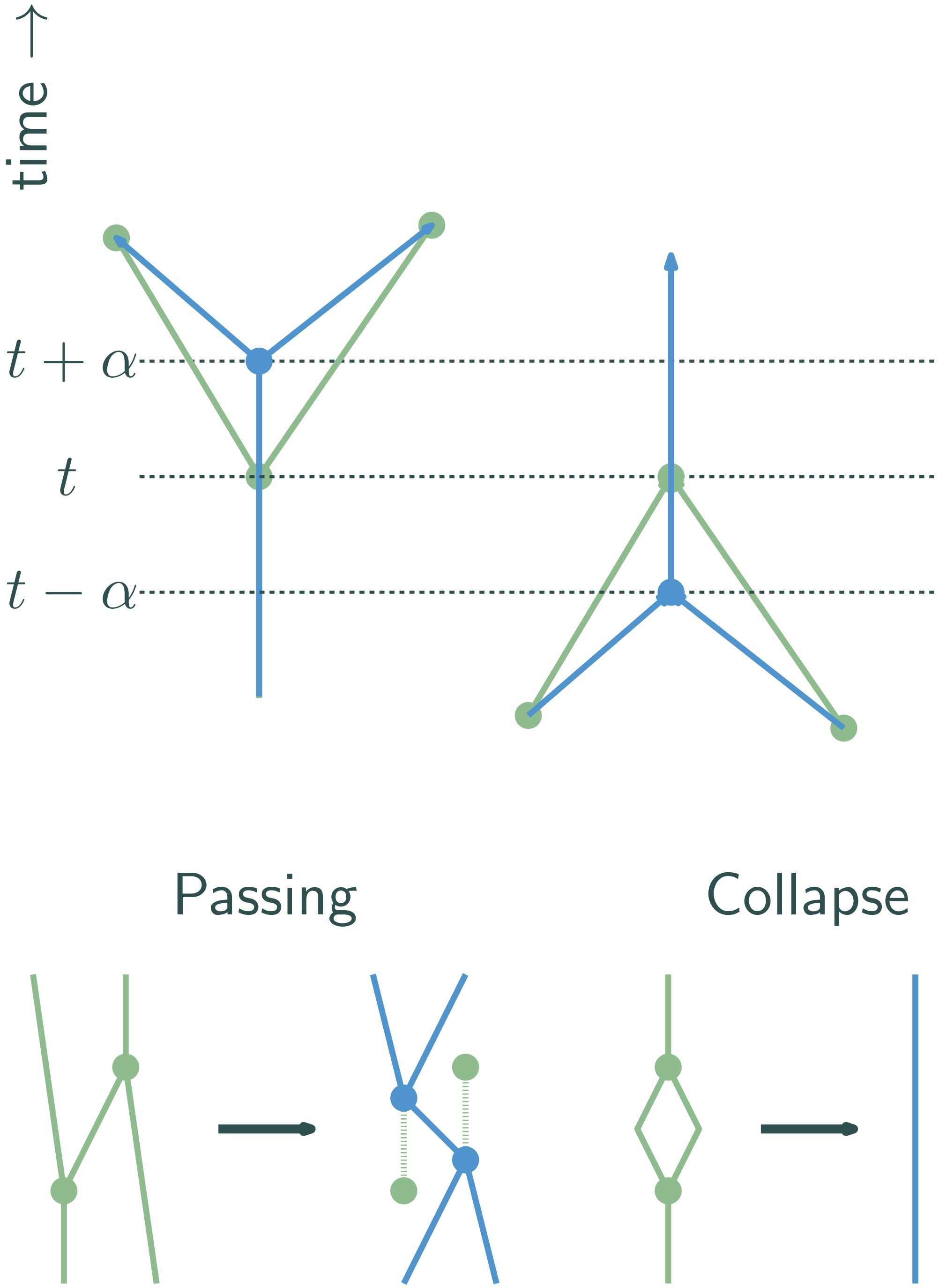
Introduce a new parameter α

x and y are in one group at time t if they are ε-connected at a time $t' \in [t-\alpha, t+\alpha]$

$\implies$

The vertices in $\mathcal{R}$ move in time.

$\mathcal{R}$ changes at encounter events.



Robustness

Introduce a new parameter α

x and y are in one group at time t if they are ε-connected at a time $t' \in [t-\alpha, t+\alpha]$

$\Longrightarrow$

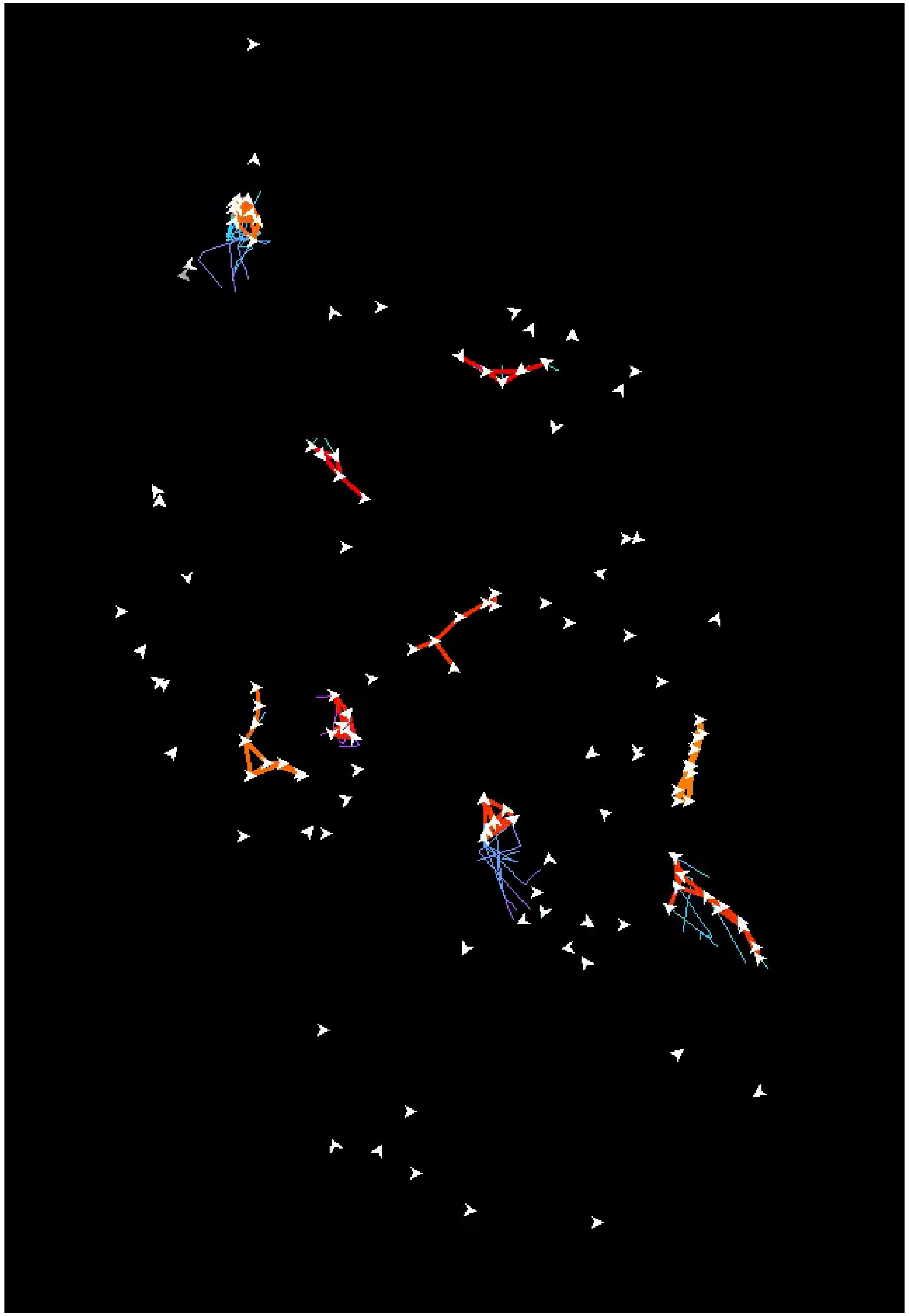
The vertices in $\mathcal{R}$ move in time.

$\mathcal{R}$ changes at encounter events.

#encounter events: $O(\tau n^3)$

we can compute them in $O(\tau n^3 \log n)$ time.

Starkey



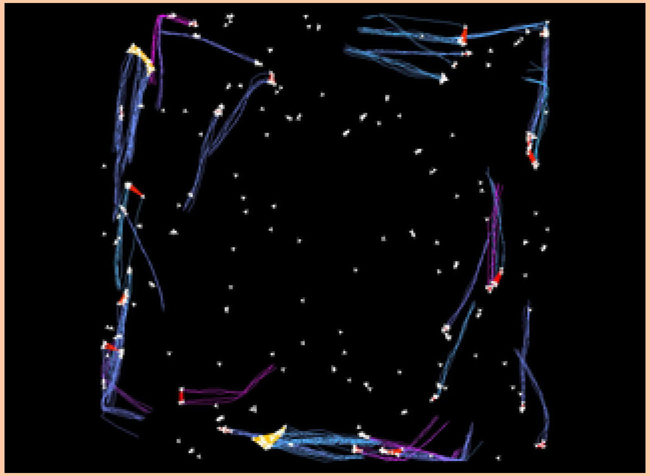
Elk (deer) tracked in Starkey (US).

$n = 126, \tau = 1264$

Evaluation

Evaluation on two data sets: Starkey and NetLogo.

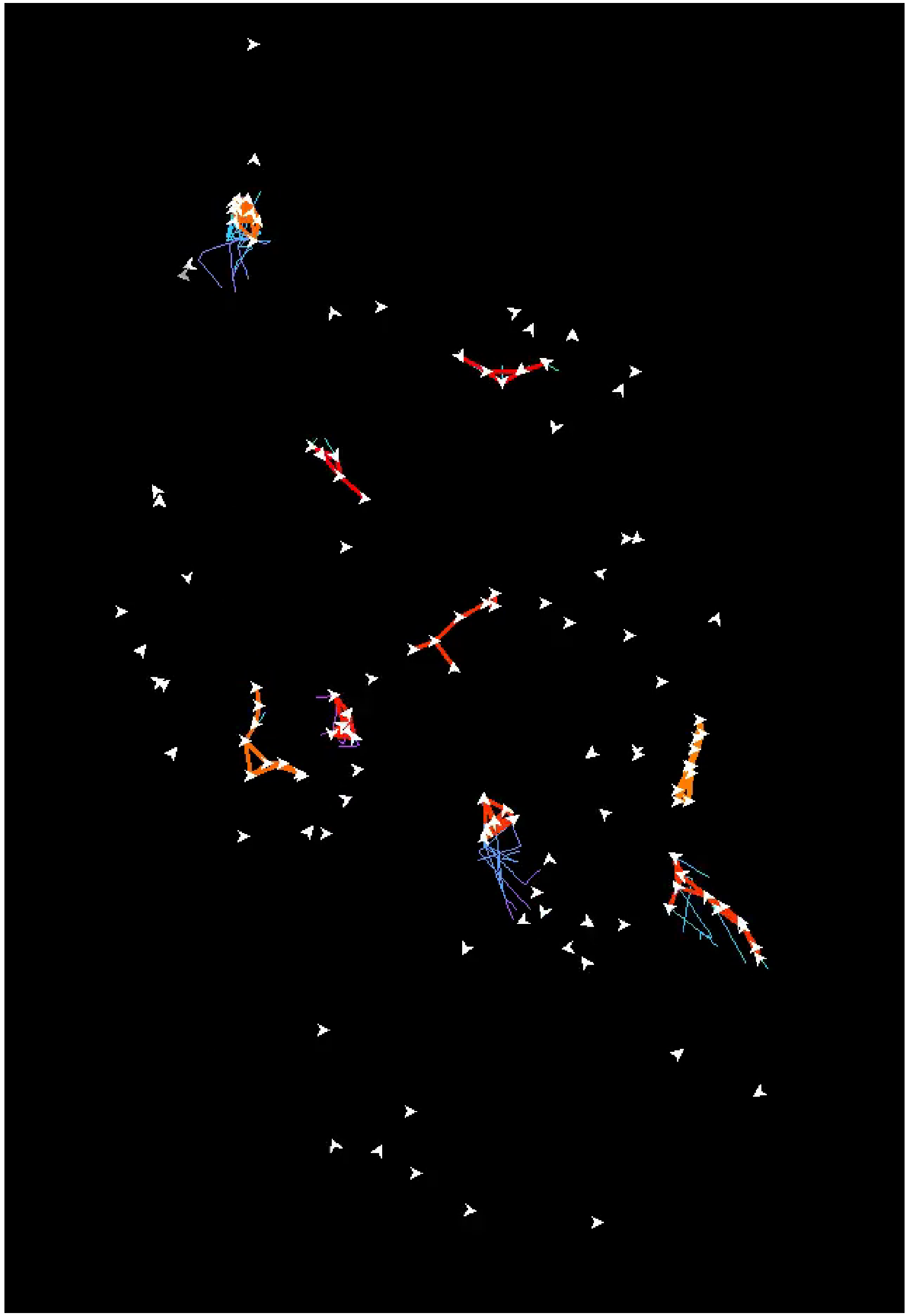
NetLogo



Based on the NetLogo flocking model.

$n = 400, \tau = 818$

Starkey



Elk (deer) tracked in Starkey (US).
$n = 126, \tau = 1264$

Evaluation

Evaluation on two data sets: Starkey and NetLogo.

Group size:

small large

Group duration:

short long

Videos on:

`www.staff.science.uu.nl/~staal006/grouping`

Starkey

Elk (deer) tracked in Starkey (US).
$n = 126, \tau = 1264$

Evaluation

Evaluation on two data sets:
Starkey and NetLogo.

Thank you!

small large

Group duration:

short long

Videos on:

`www.staff.science.uu.nl/~staal006/grouping`