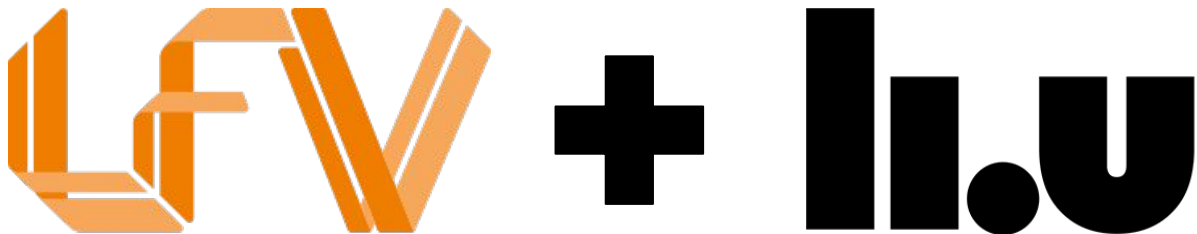


Towards Simplified Optimal Sector Splitting

Billy Josefsson - LFV

Valentin Polishchuk, **Leonid Sedov** - Linköping University

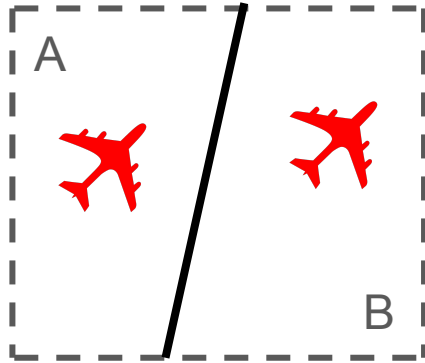


dynamic Demand Capacity Balancing (dCDB)

Traffic density - changing

Sectors - static

9:00 AM



Controller **A** - 😊

Controller **B** - 😊

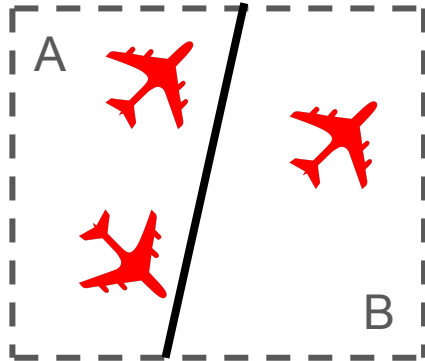
Everyone is happy! For how long?

dynamic Demand Capacity Balancing (dCDB)

Traffic density - changing

Sectors - static

12:00



Controller **A** - 😞

Controller **B** - 😊

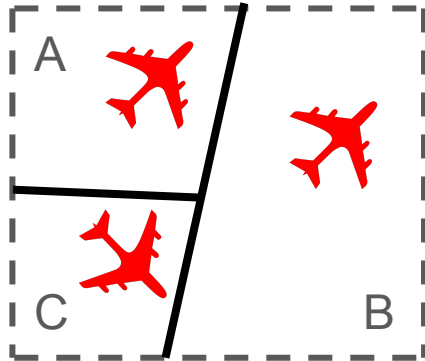
Solution?

dynamic Demand Capacity Balancing (dCDB)

Traffic density - changing

Sectors - static

12:00



Controller **A** - 😊

Controller **B** - 😊

Controller **C** - 😊

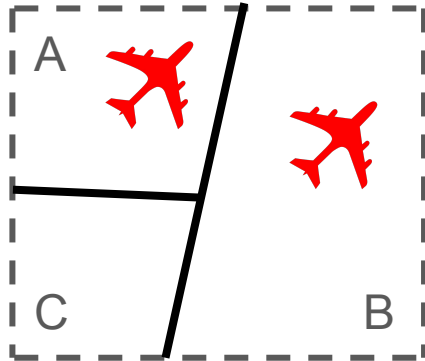
Everyone is happy again

dynamic Demand Capacity Balancing (dCDB)

Traffic density - changing

Sectors - static

14:00



Controller **A** - 😊
Controller **B** - 😊
Controller **C** - 😴

\$\$\$

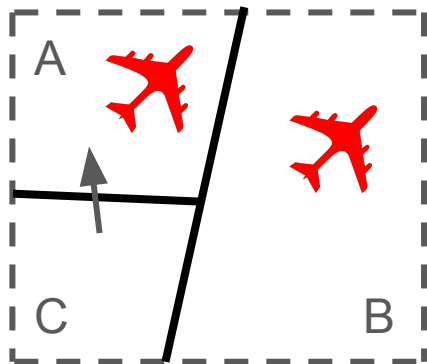
Do we need sector C?

dynamic Demand Capacity Balancing (dCDB)

Traffic density - changing

Sectors - static

14:00



Controller **A** - 😊

Controller **B** - 😊

Controller **C** - 😴

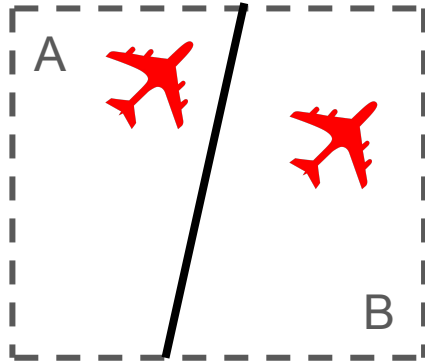
Do we need sector C?

dynamic Demand Capacity Balancing (dCDB)

Traffic density - changing

Sectors - static

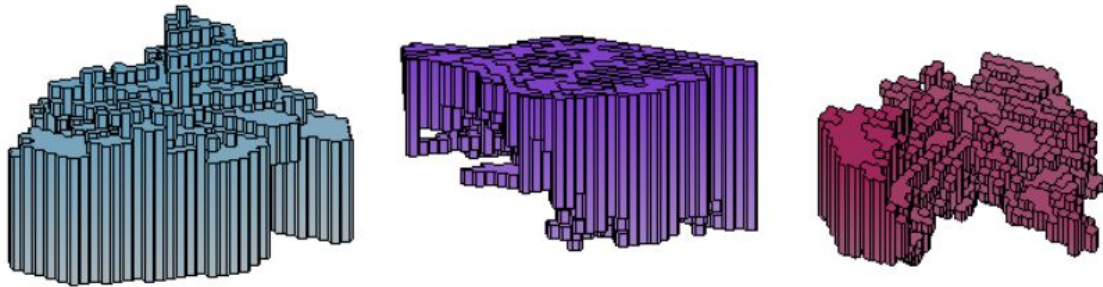
14:00



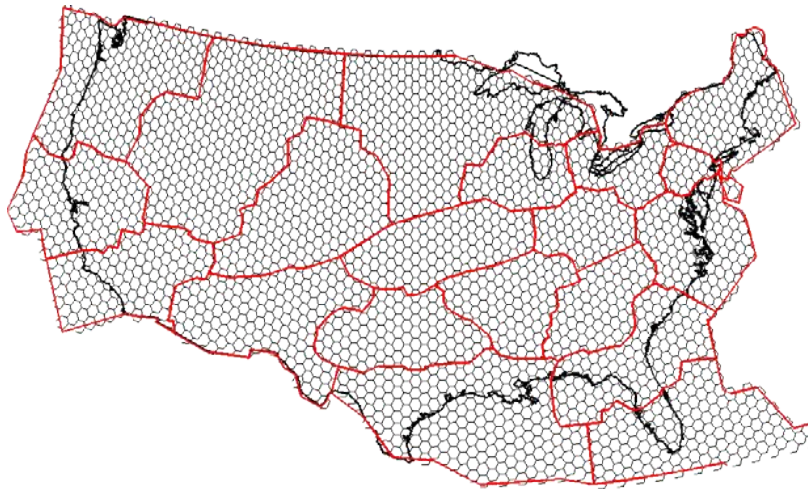
Controller **A** - 😊

Controller **B** - 😊

Gluing

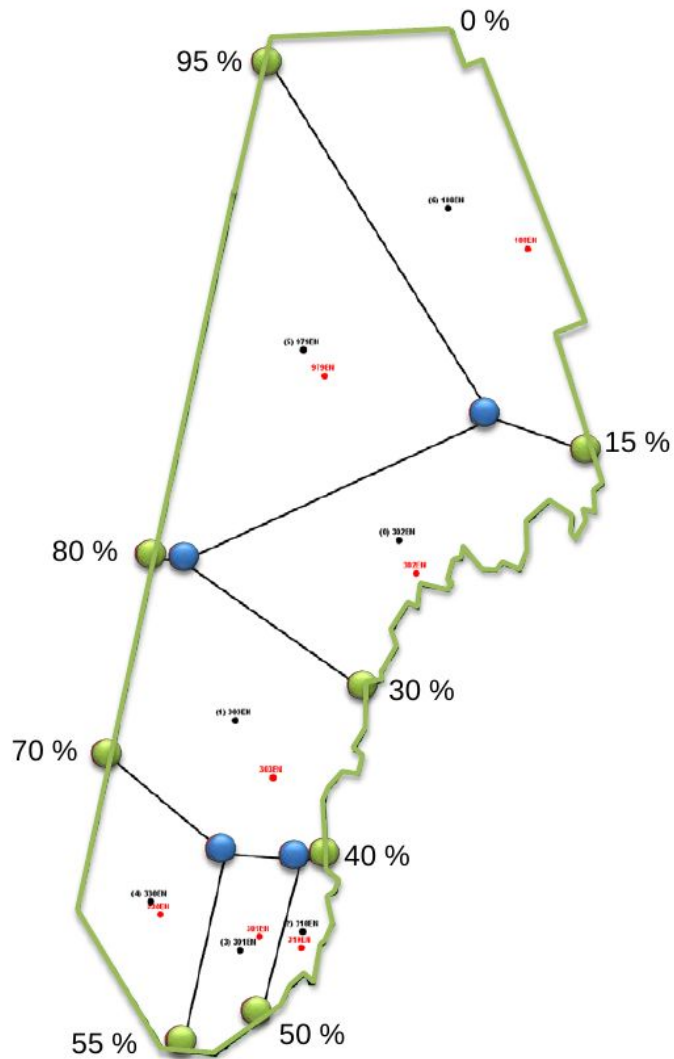


[Kjellin '14]



[Yousefi and Donohue '04]

Cutting

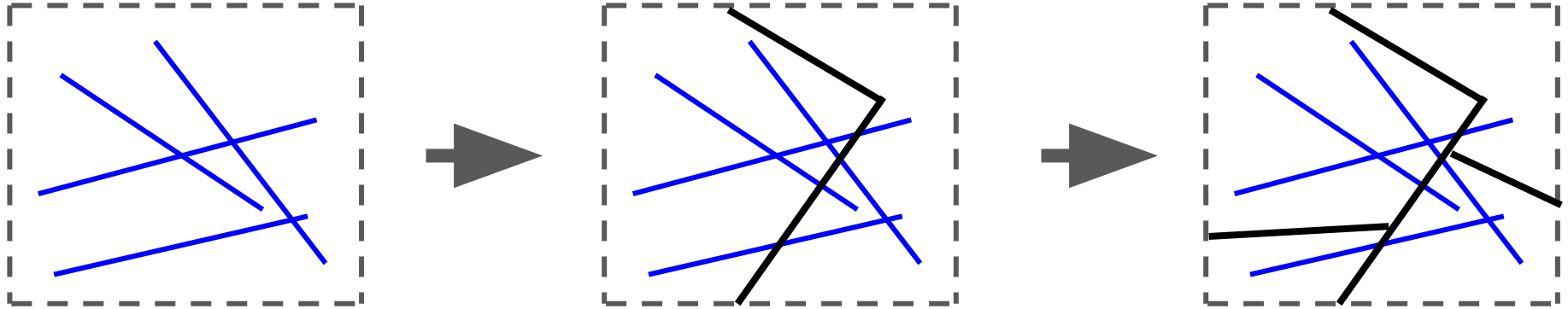


[Gerdes et al., SID'16]

Binary split

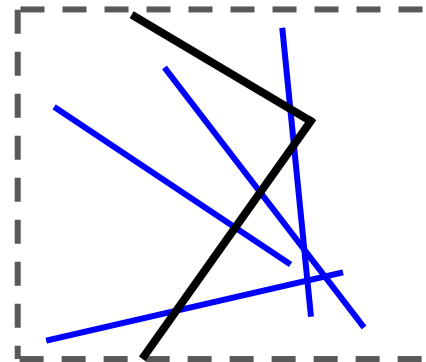
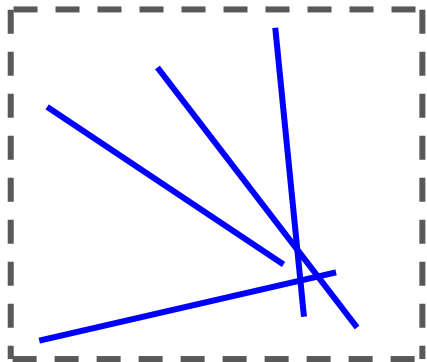
Split airspace into 2 parts

Need more sectors? - Do recursive split.



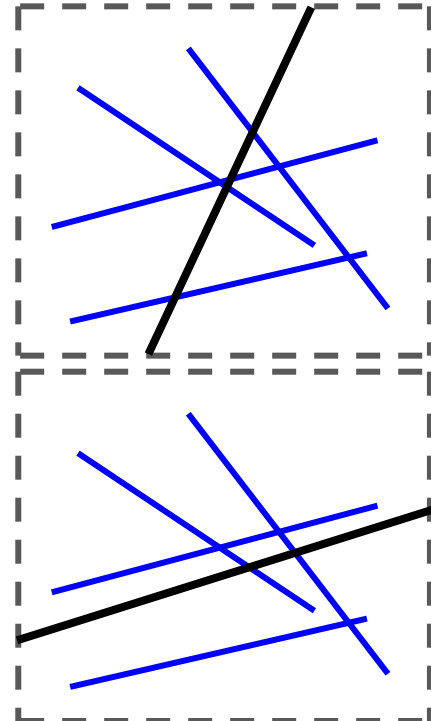
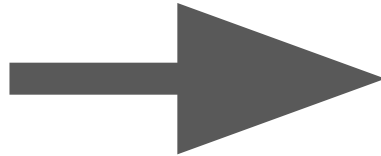
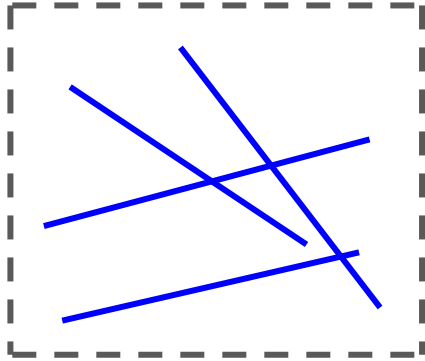
Convex boundaries

Line segment intersects convex region at most once



Straightline cuts

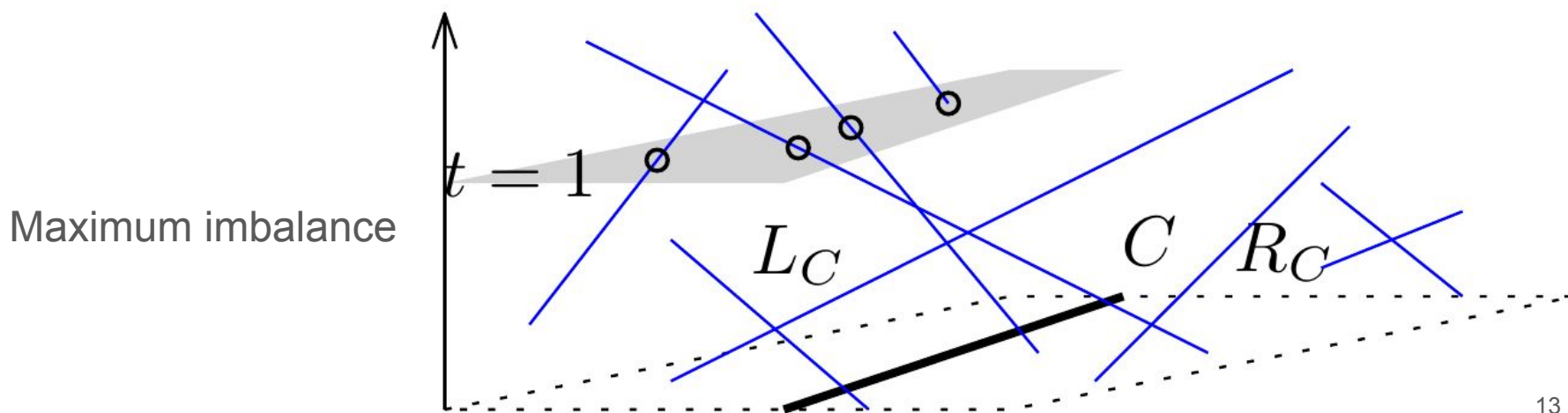
Chord joins two points on boundary



KPIs

Maximum imbalance - **peak** complexity

Average imbalance - **total** complexity

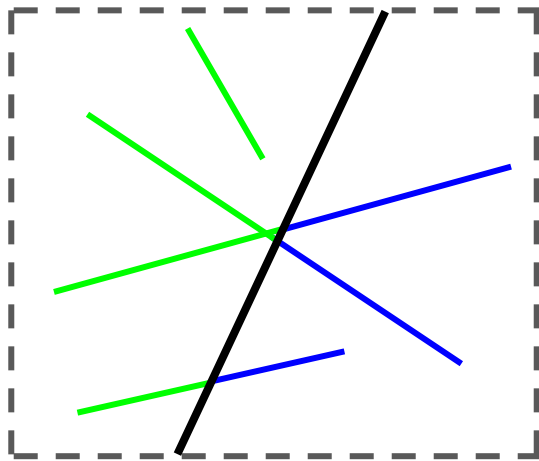


KPIs

Maximum imbalance - **peak** complexity

Average imbalance - **total** complexity

Average imbalance

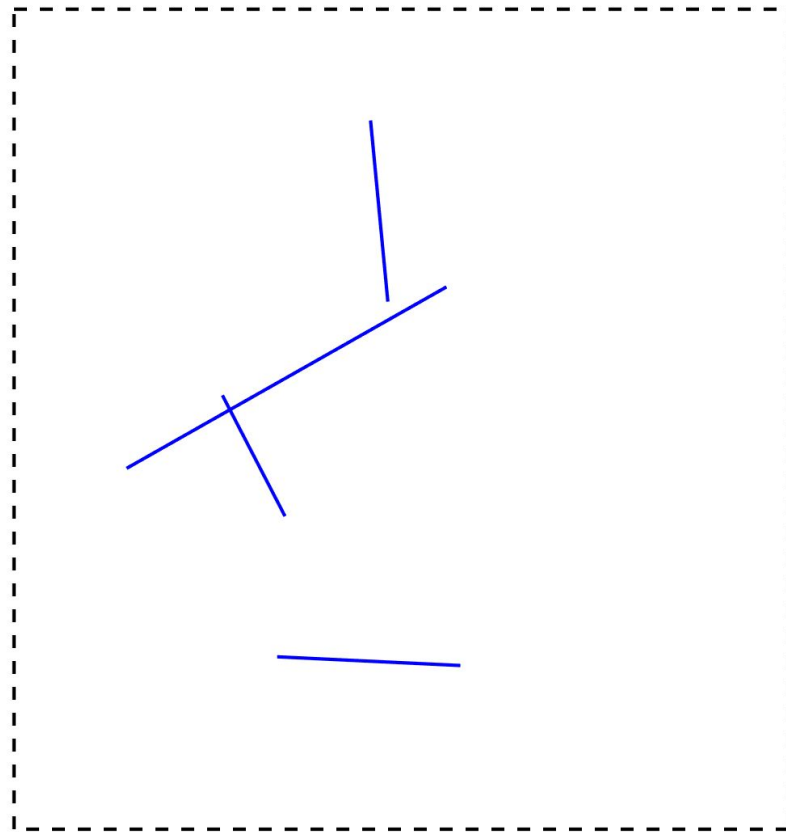


Balance max or avg?

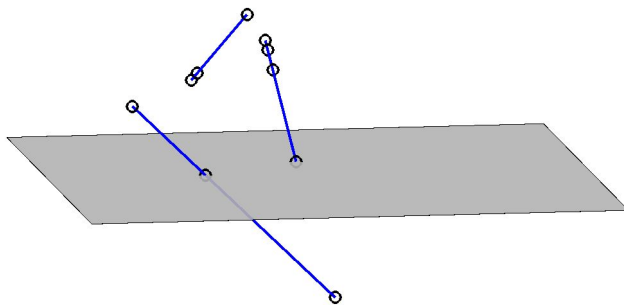
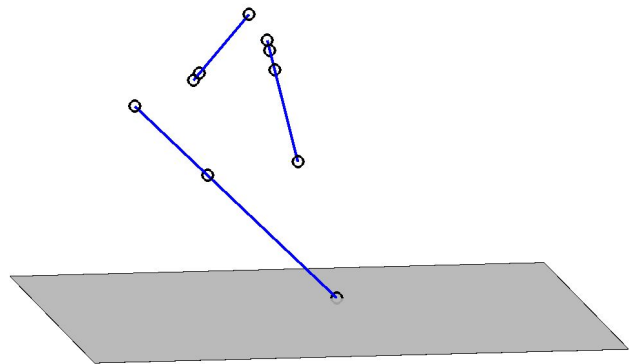
- We can both!

Input

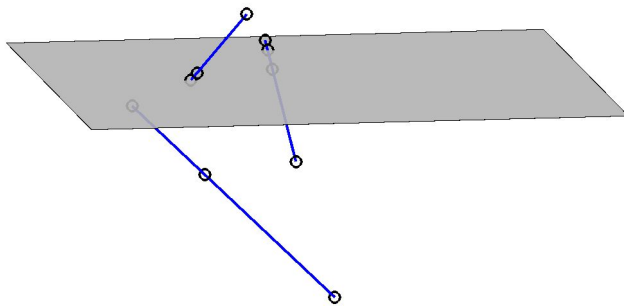
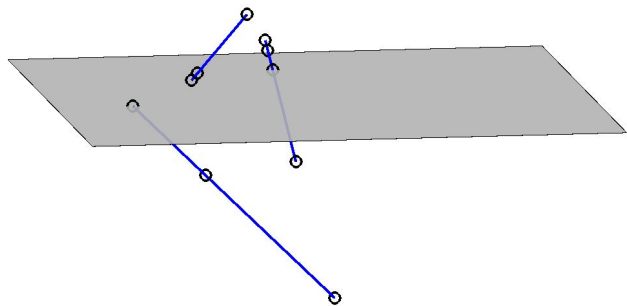
- Region P
- Set S of straightline flight segments
 - Segment start and end coordinates
 - Times when aircraft enters and leaves segment



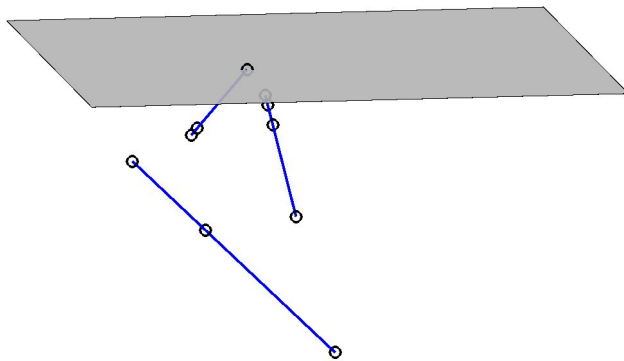
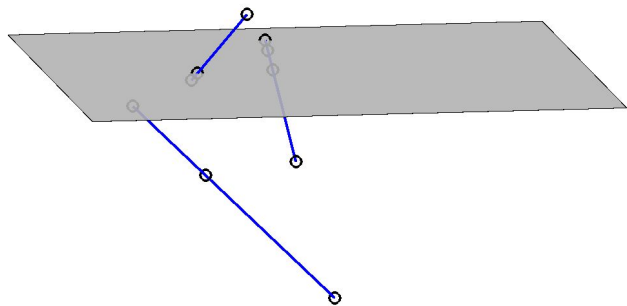
Critical points



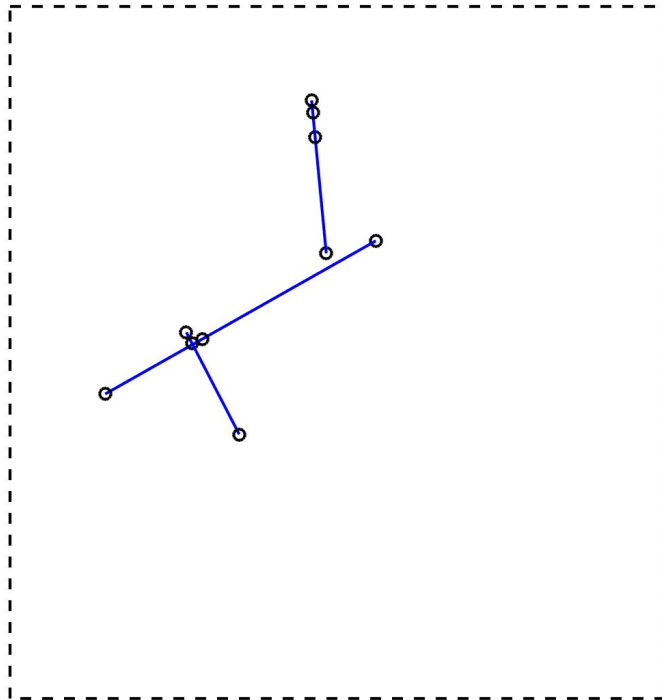
Critical points



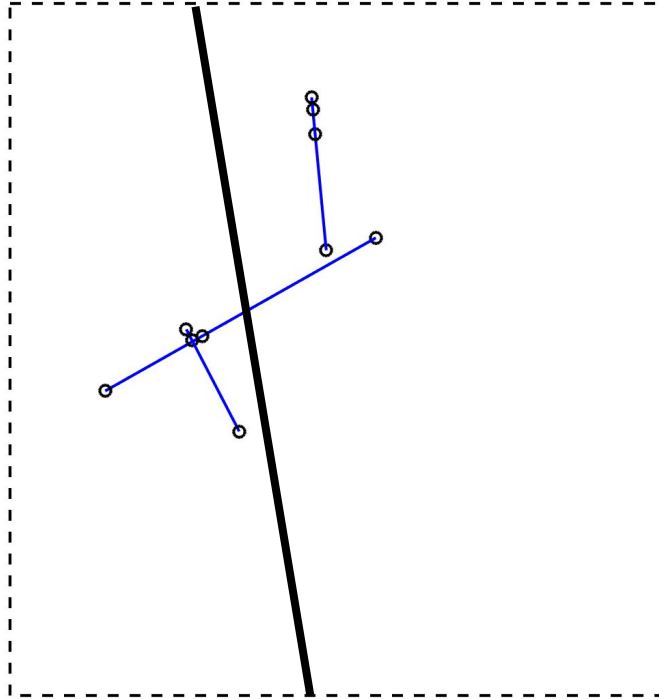
Critical points



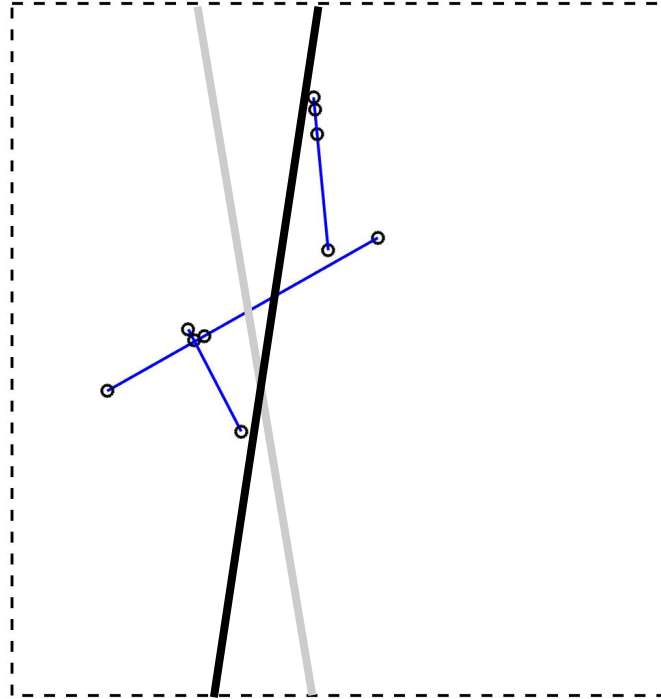
Critical points



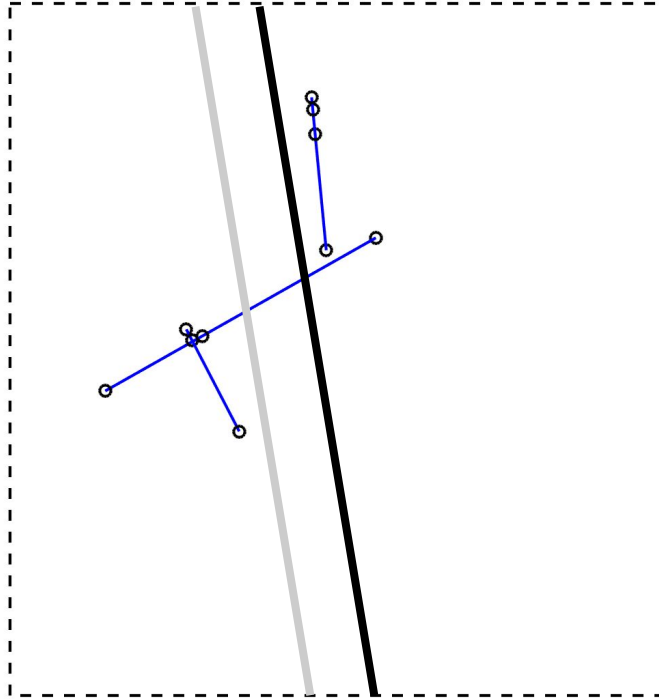
Critical points



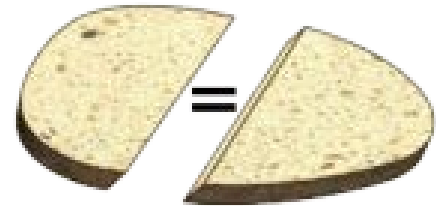
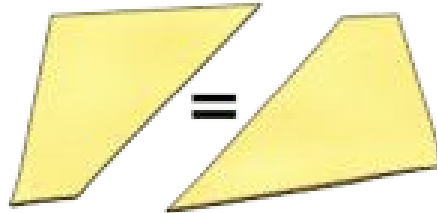
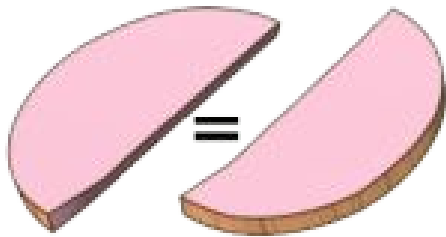
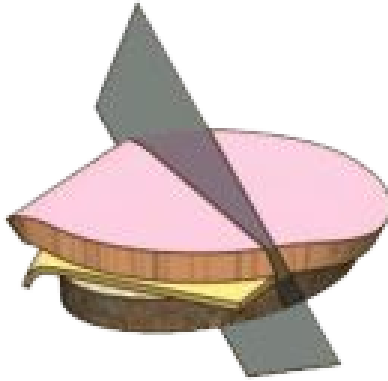
Critical points



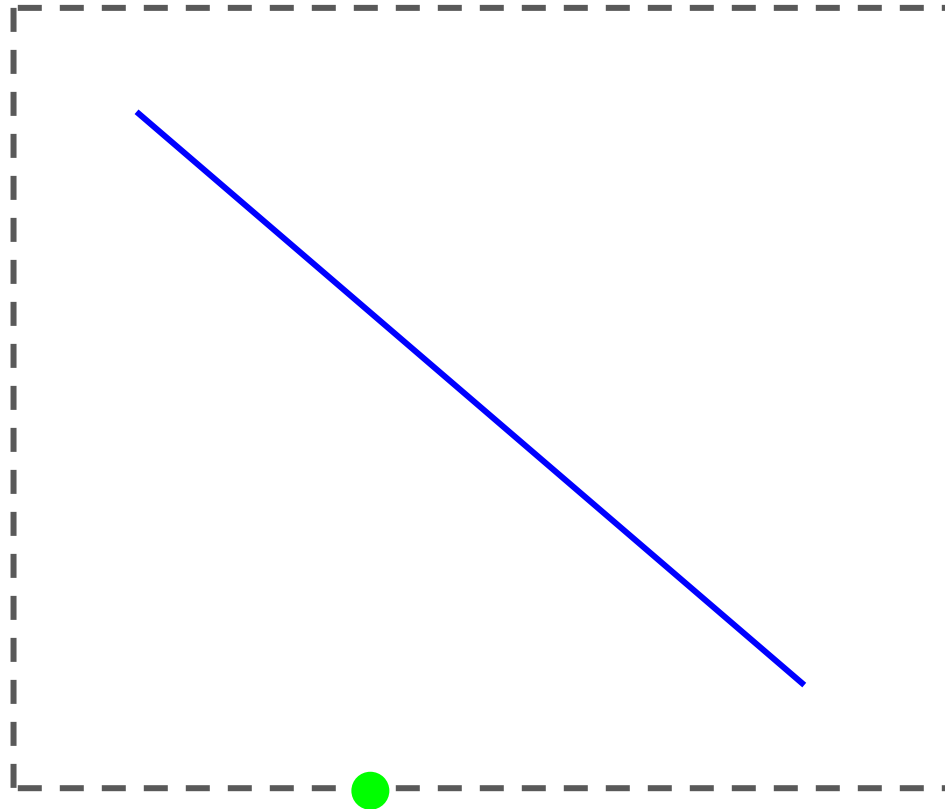
Critical points



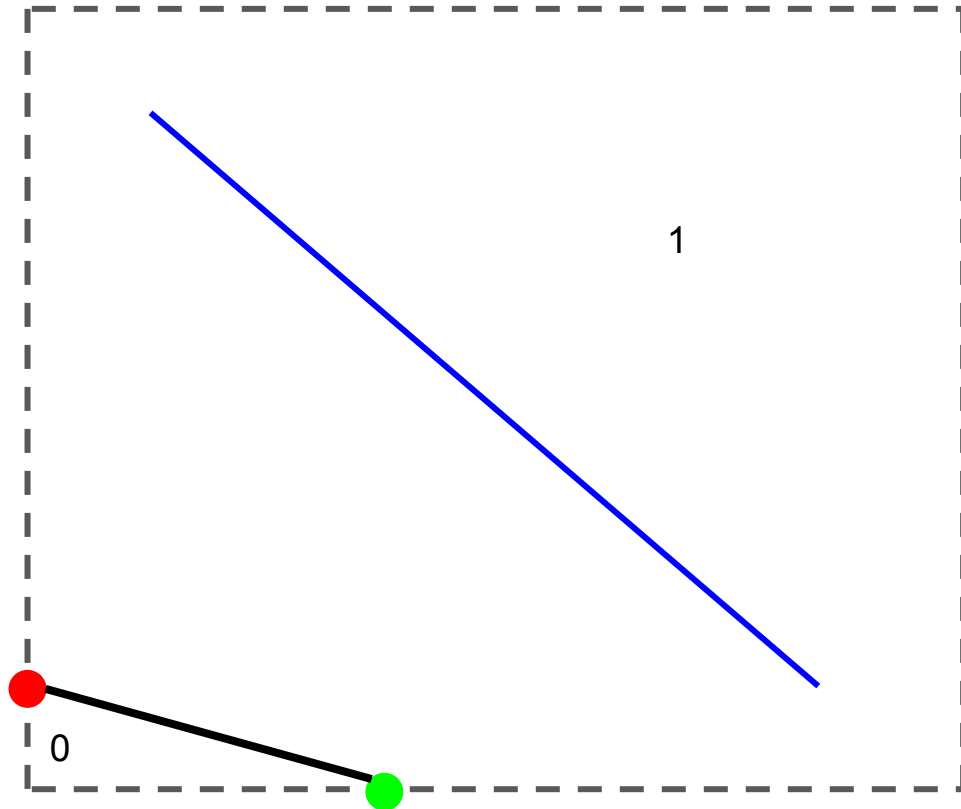
Ham sandwich theorem



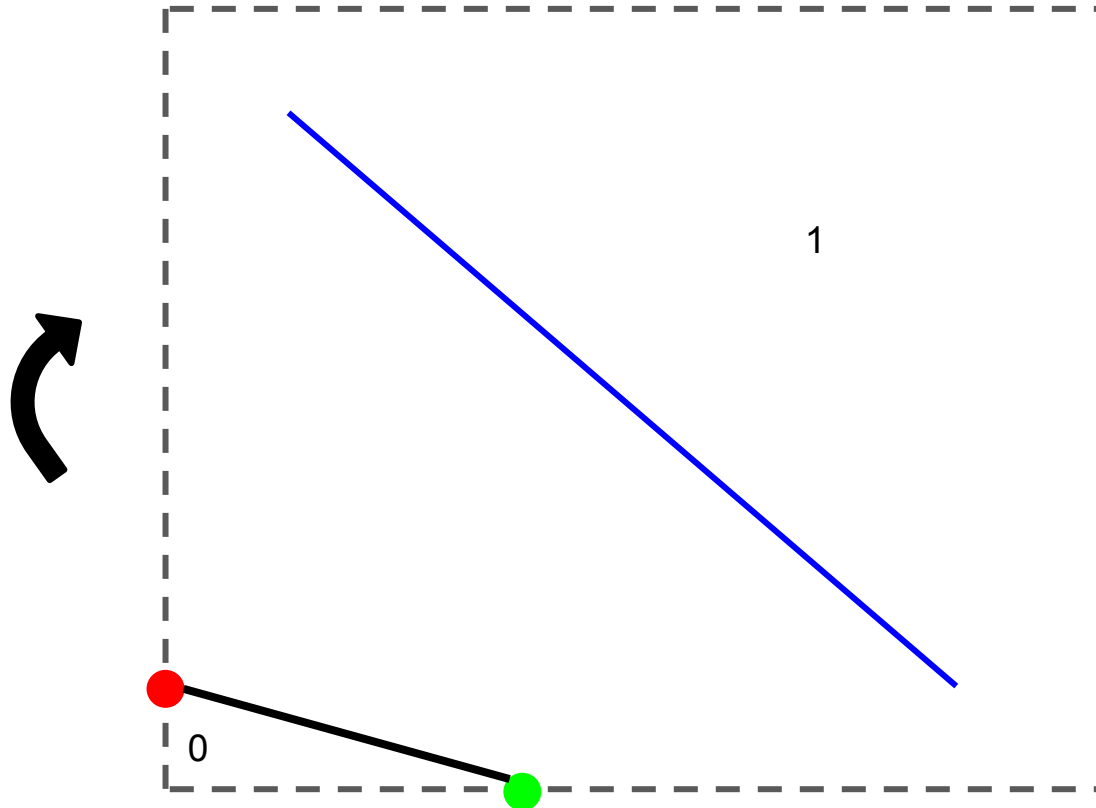
Proof: $\text{avg} = 0$ split exists for each point



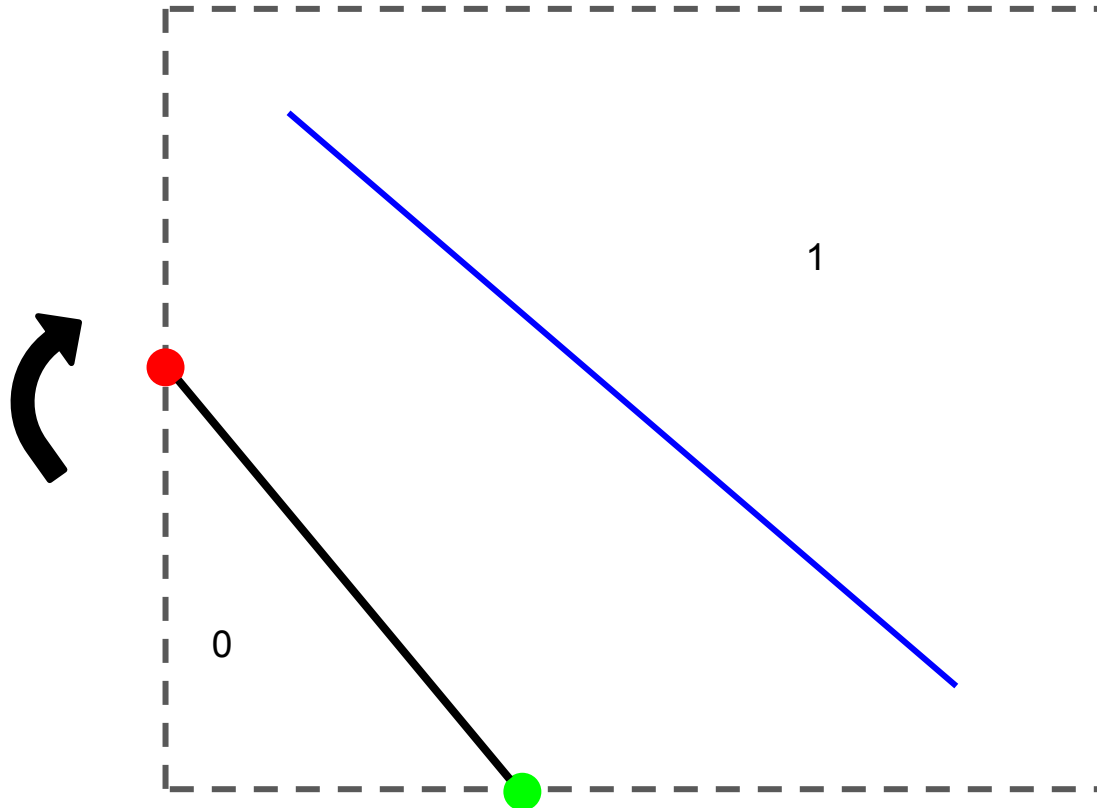
Proof: $\text{avg} = 0$ split exists for each point



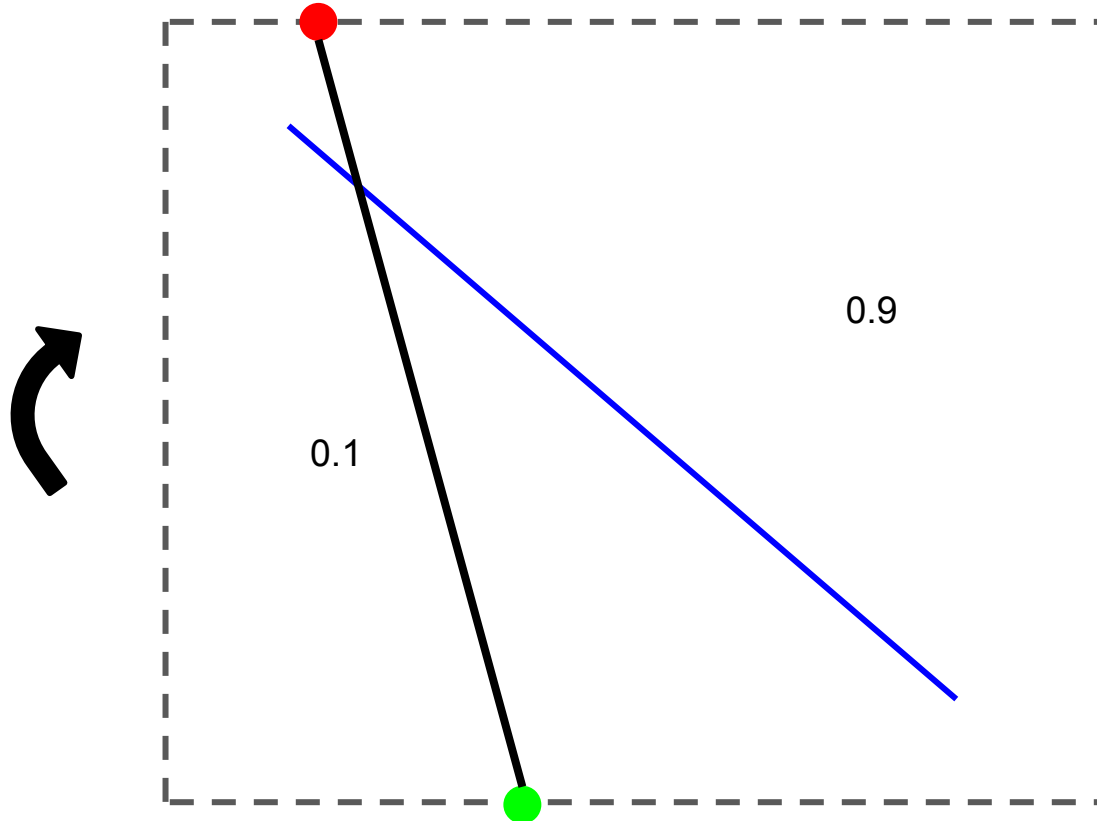
Proof: $\text{avg} = 0$ split exists for each point



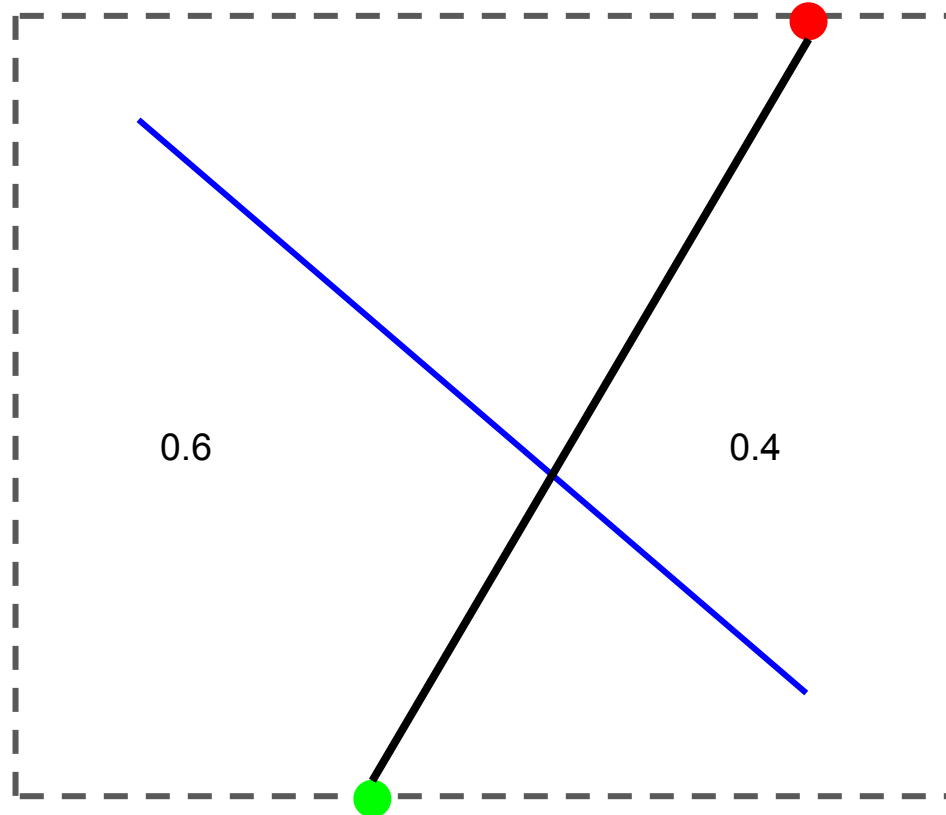
Proof: $\text{avg} = 0$ split exists for each point



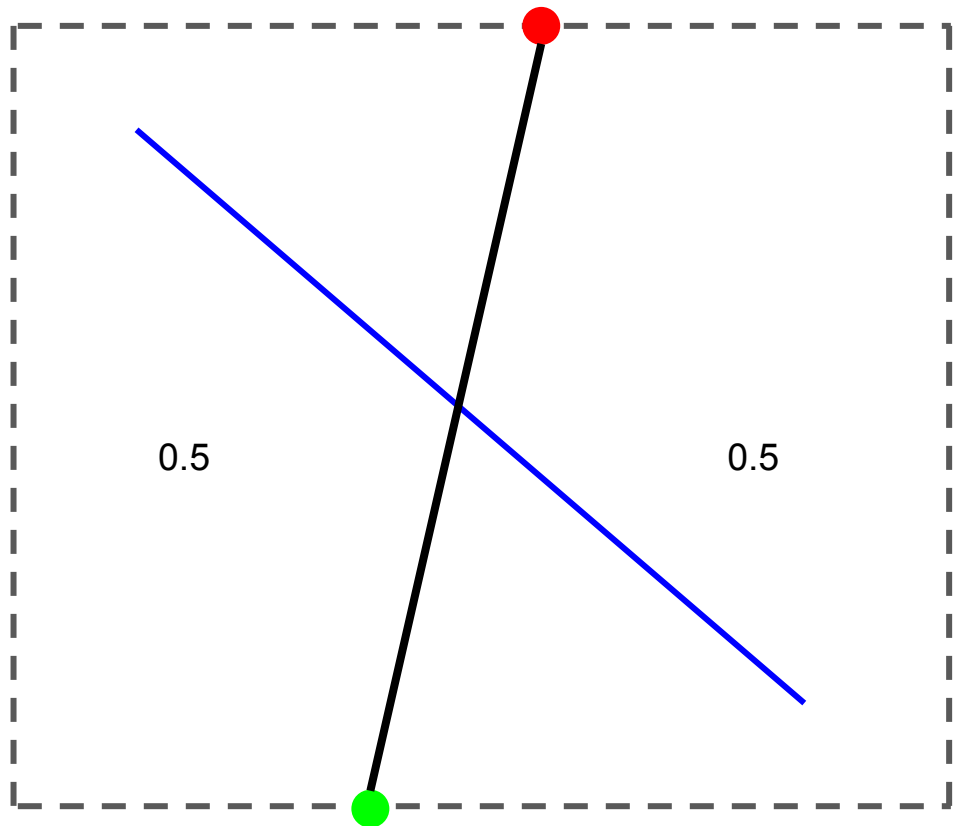
Proof: $\text{avg} = 0$ split exists for each point



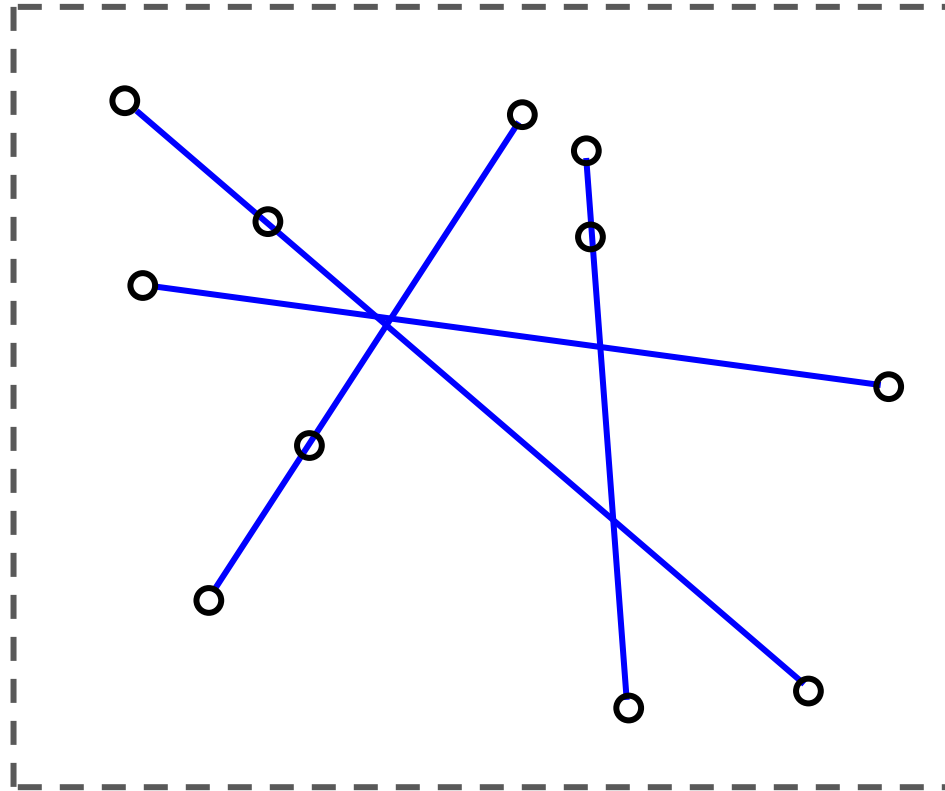
Proof: $\text{avg} = 0$ split exists for each point



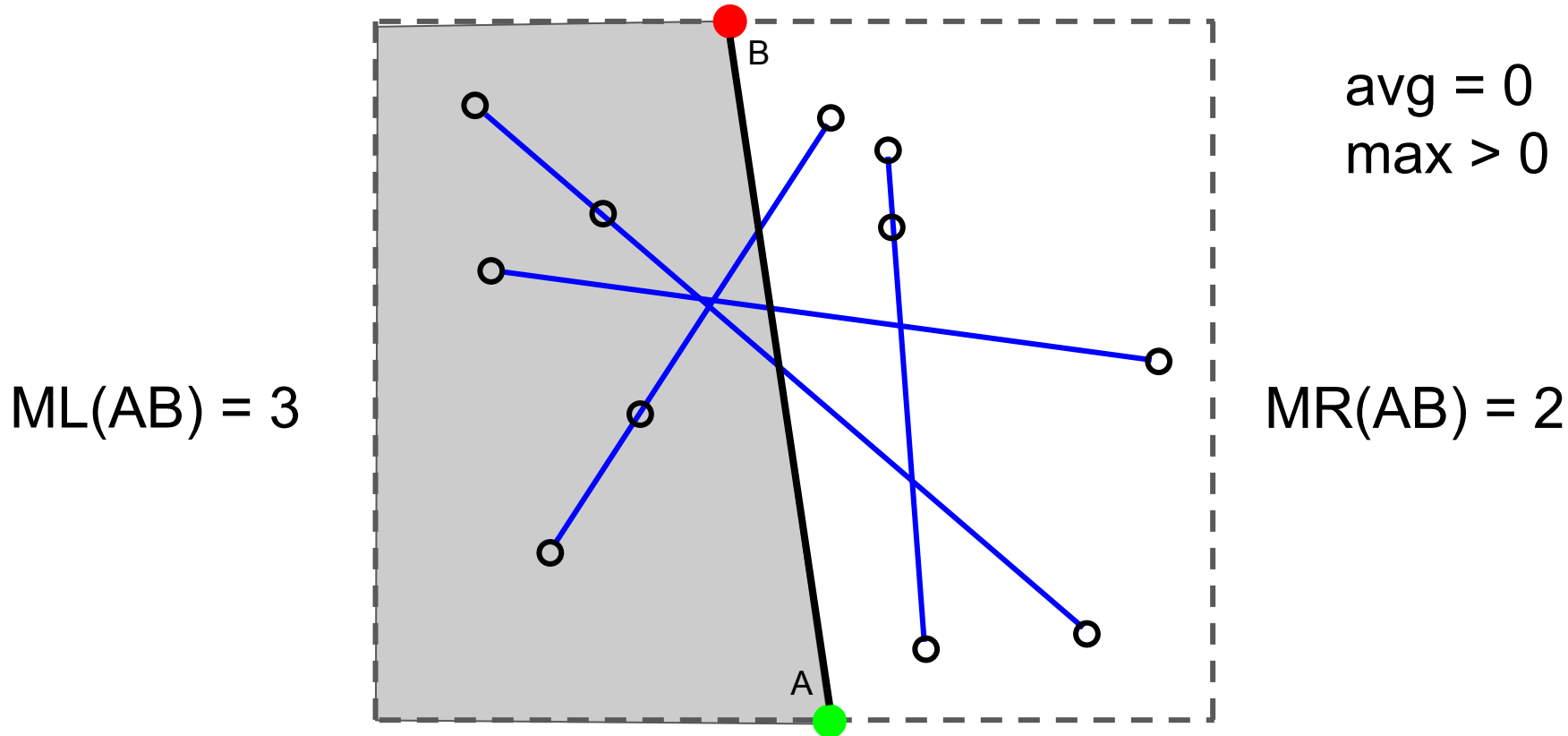
Proof: $\text{avg} = 0$ split exists for each point



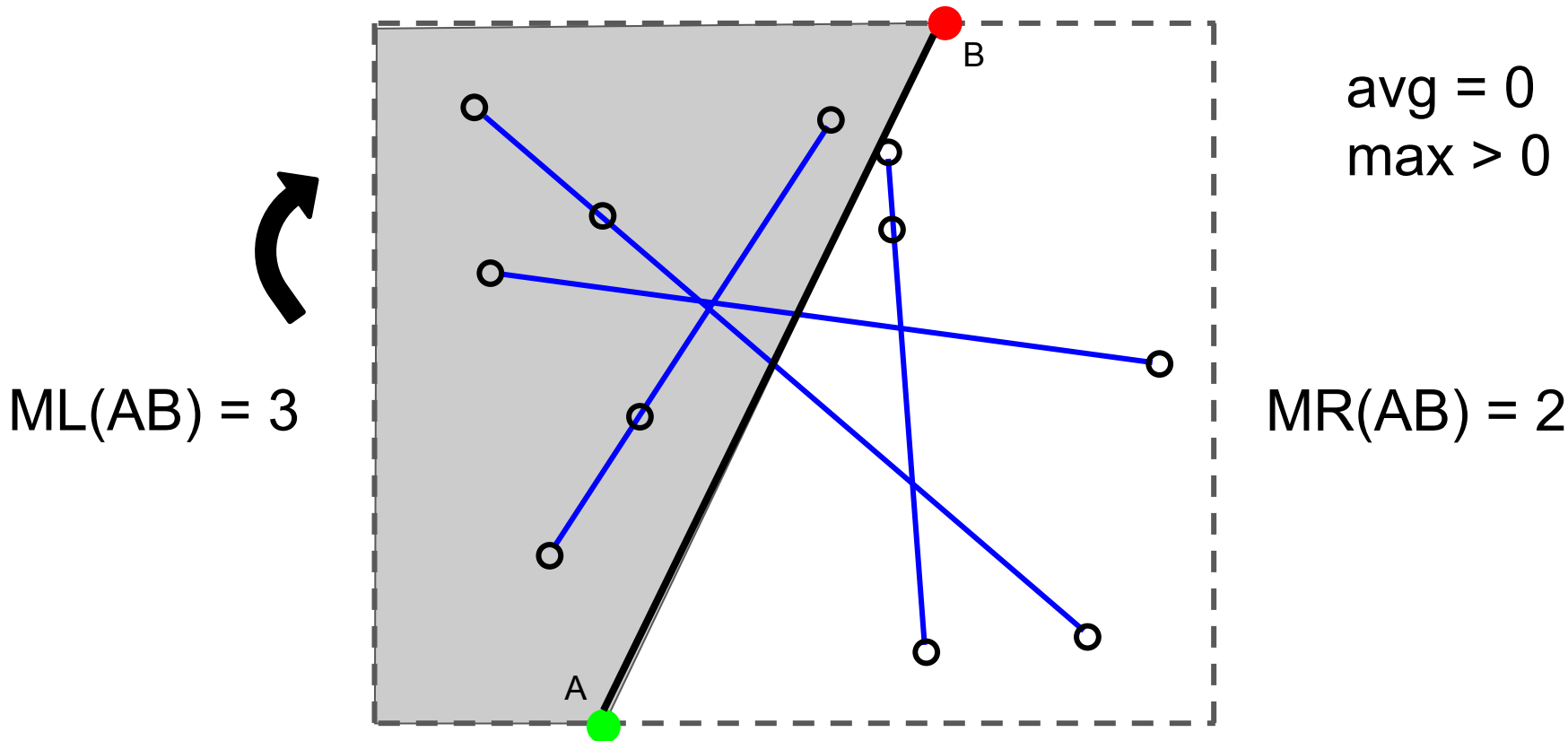
Proof: exists max & avg = 0 split



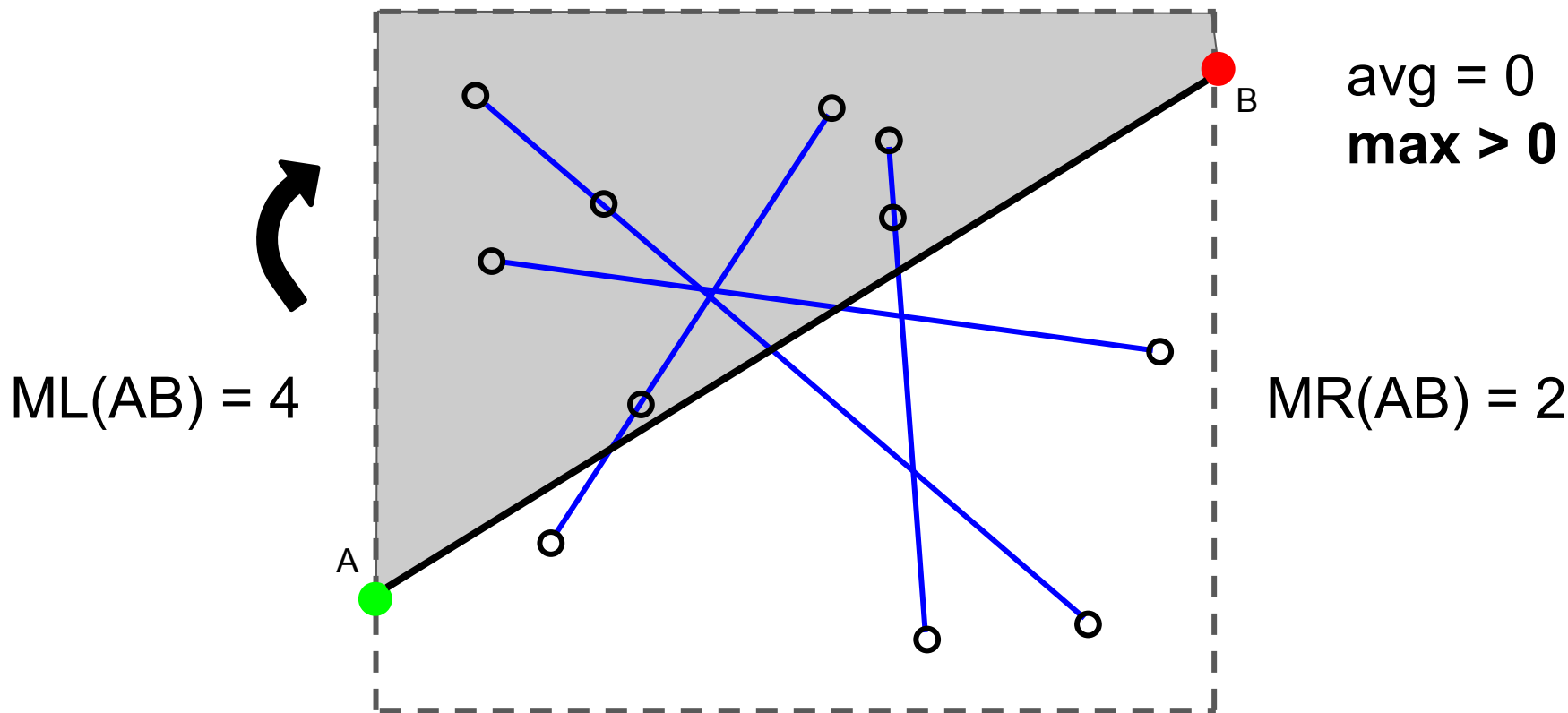
Proof: exists max & avg = 0 split



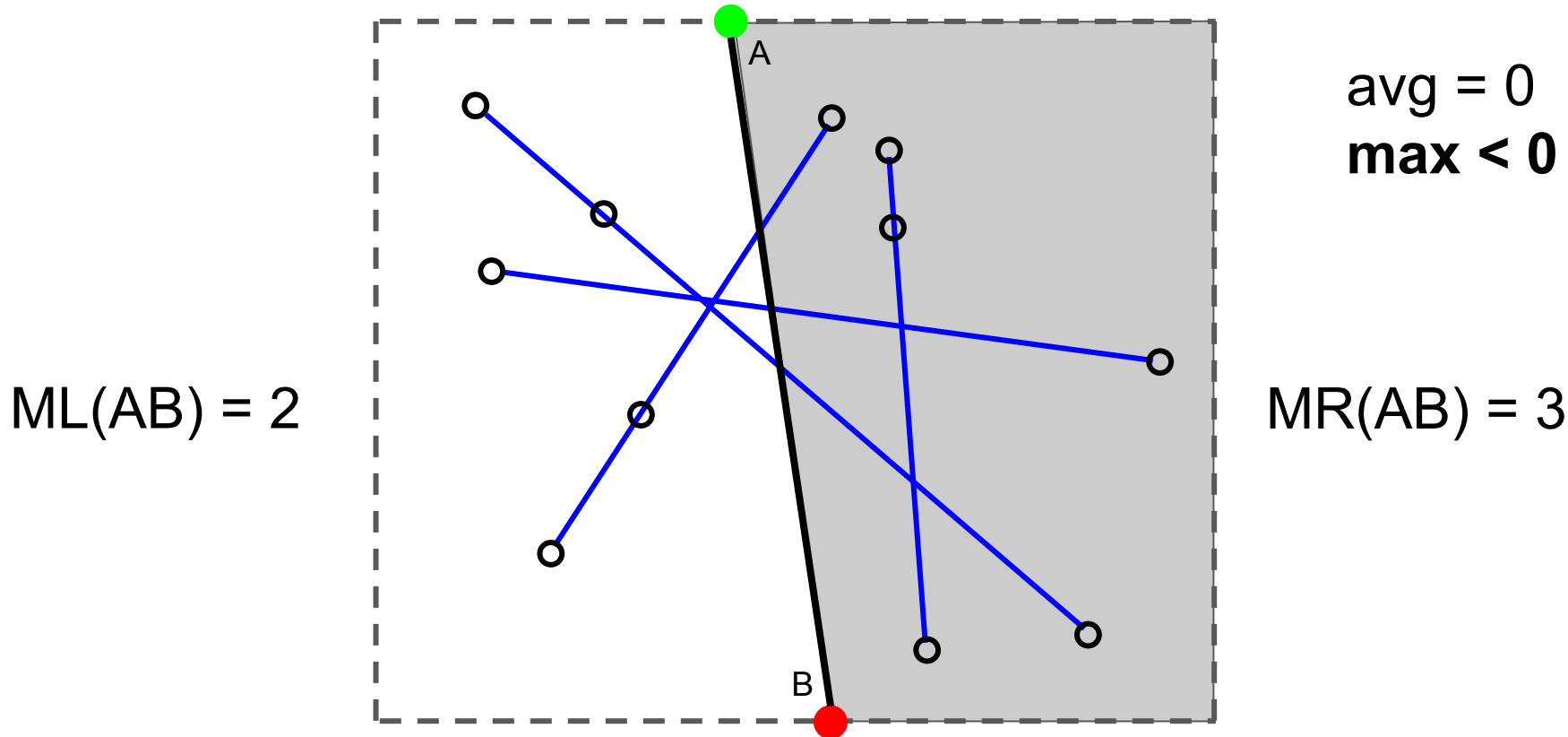
Proof: exists max & avg = 0 split



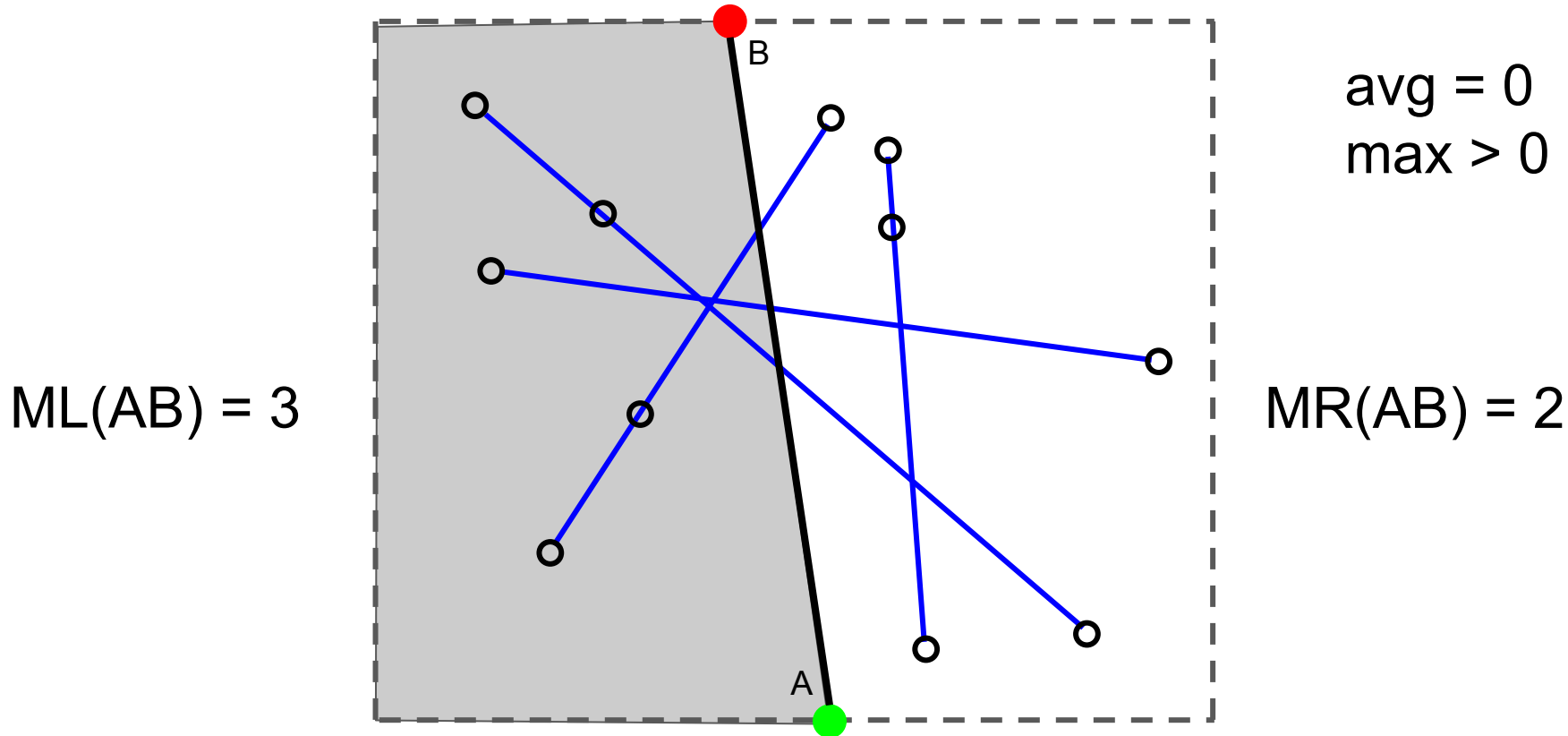
Proof: exists max & avg = 0 split



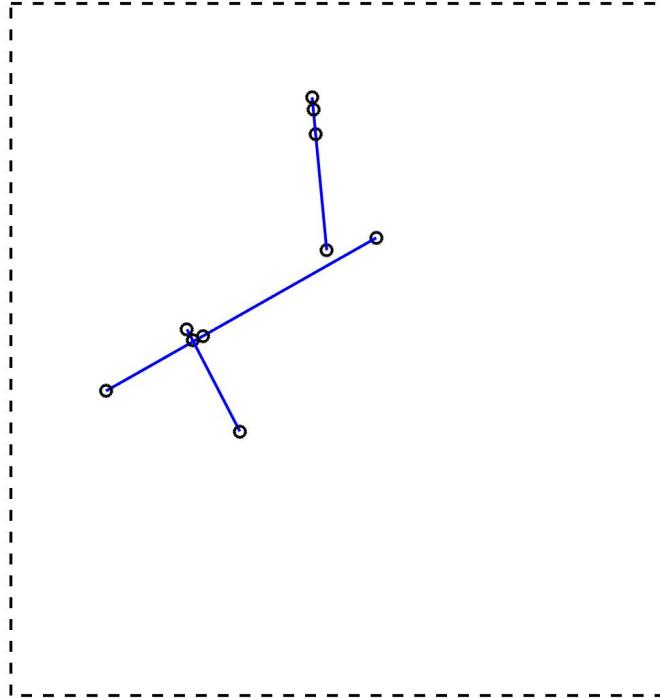
Proof: exists max & avg = 0 split



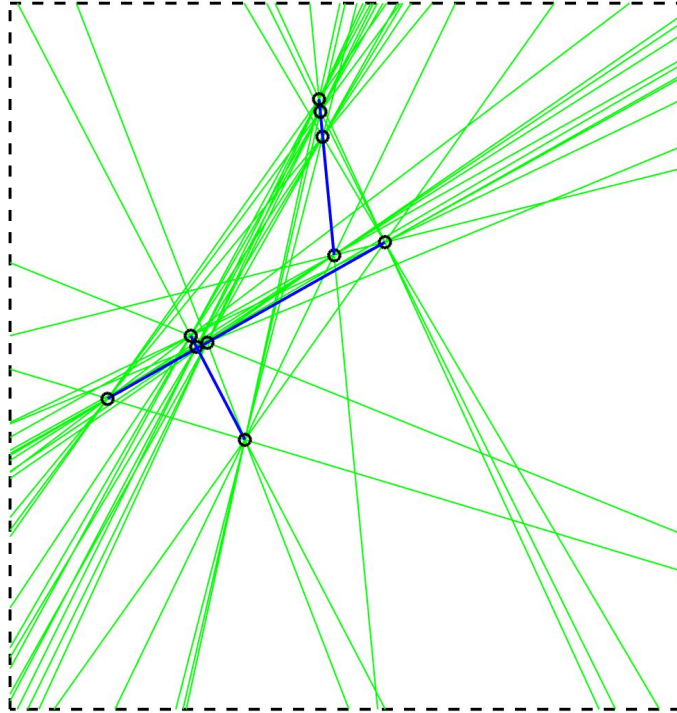
Proof: exists max & avg = 0 split



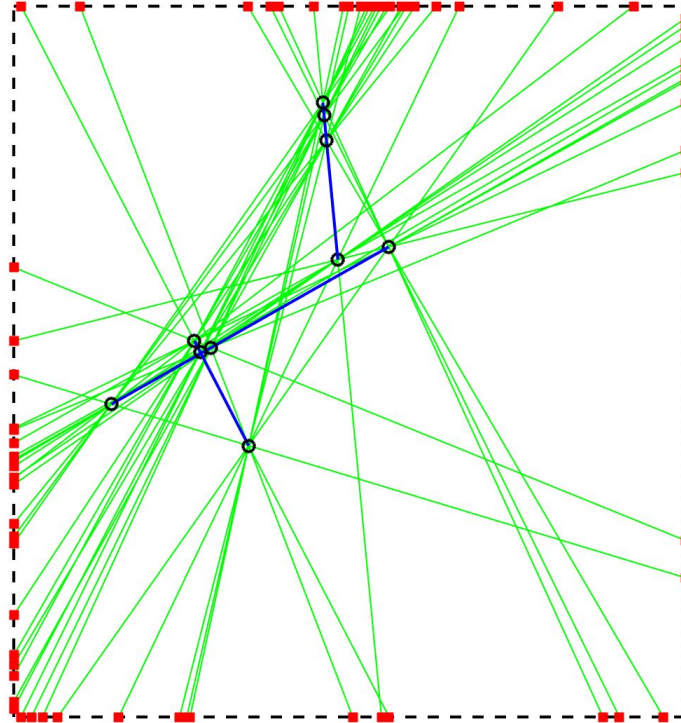
1: Find critical points



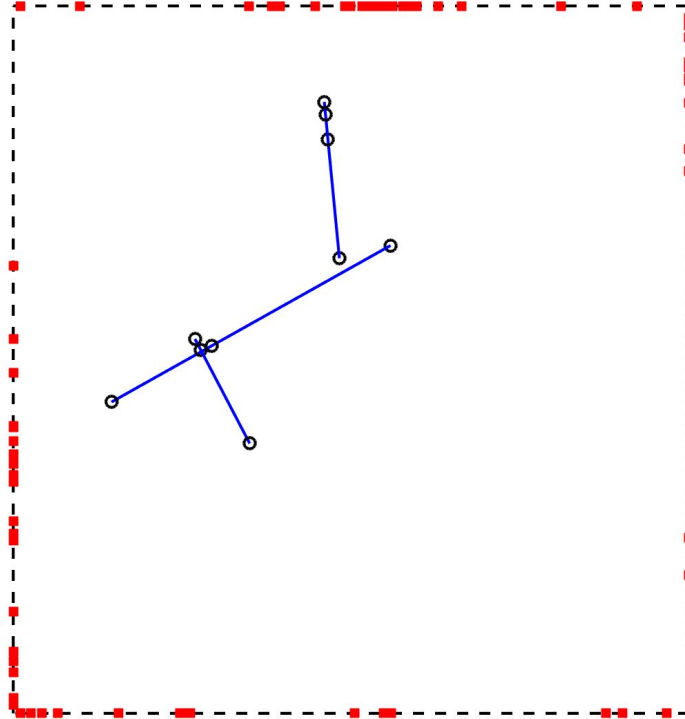
2: Lines through all pairs of critical points



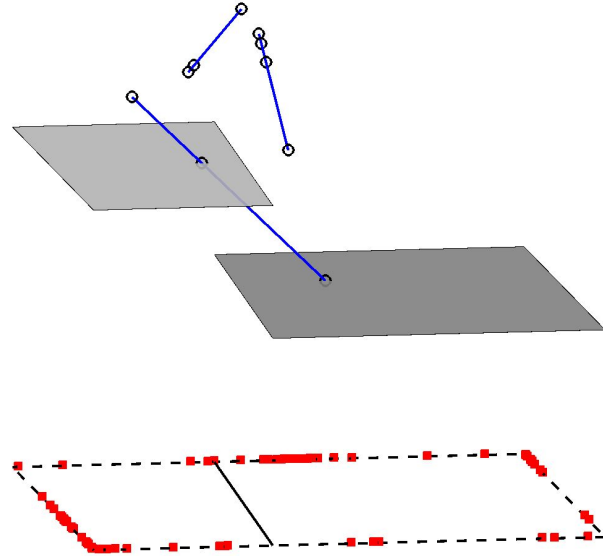
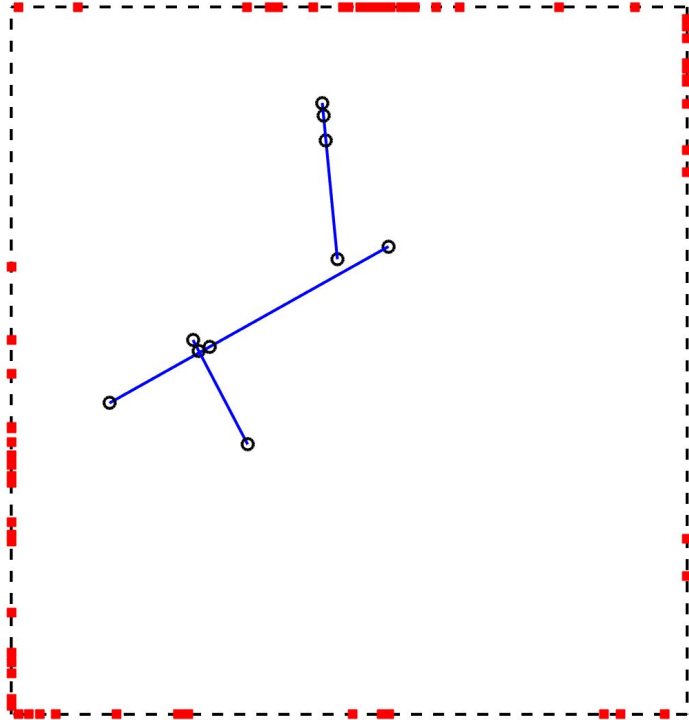
2: Lines through all pairs of critical points



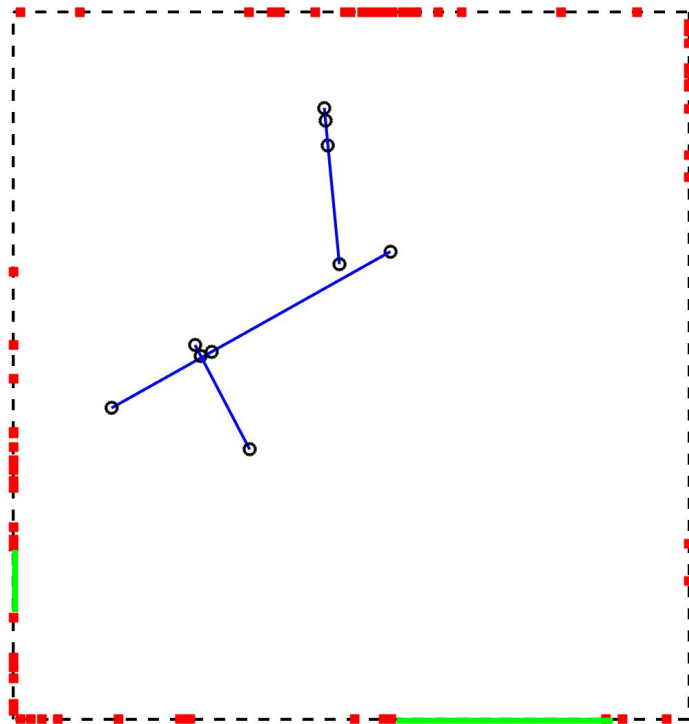
2: Lines through all pairs of critical points



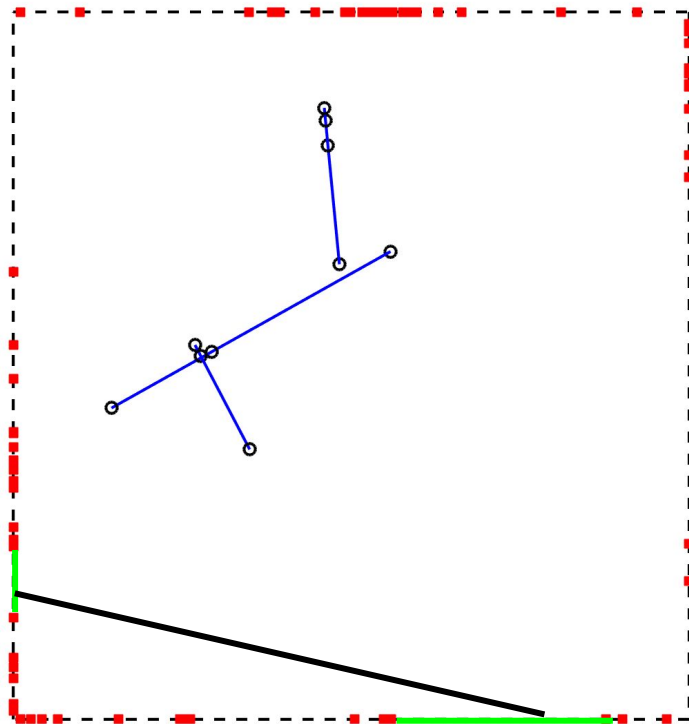
3: Find pairs of intervals with 0 M-imbalance



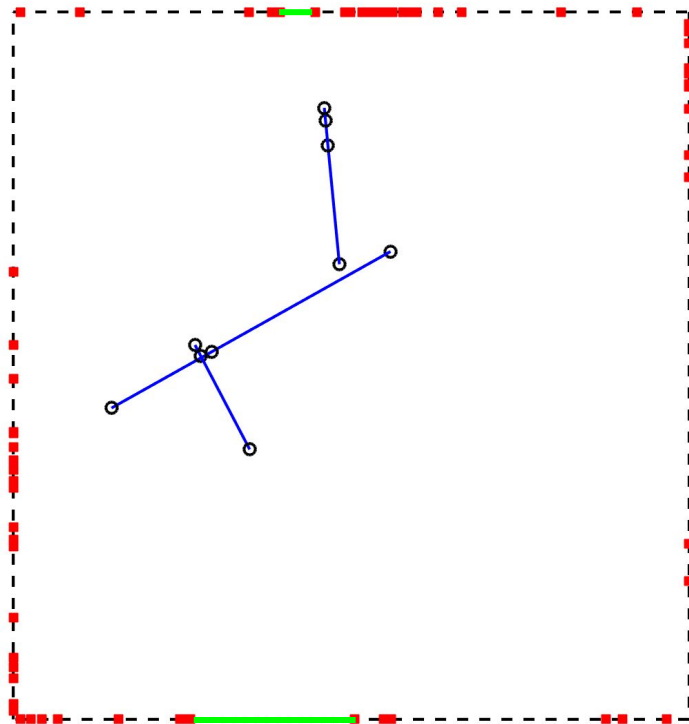
3: Find pairs of intervals with 0 M-imbalance



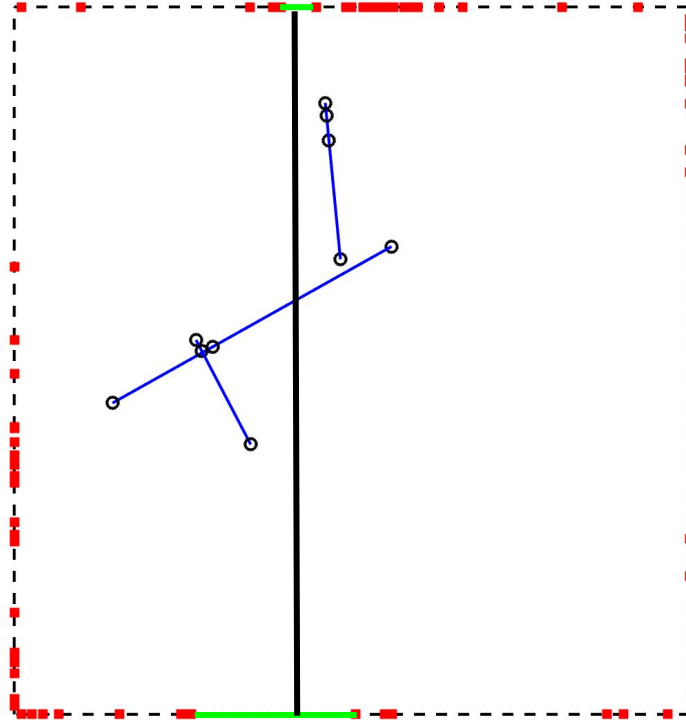
3: Find pairs of intervals with 0 M-imbalance



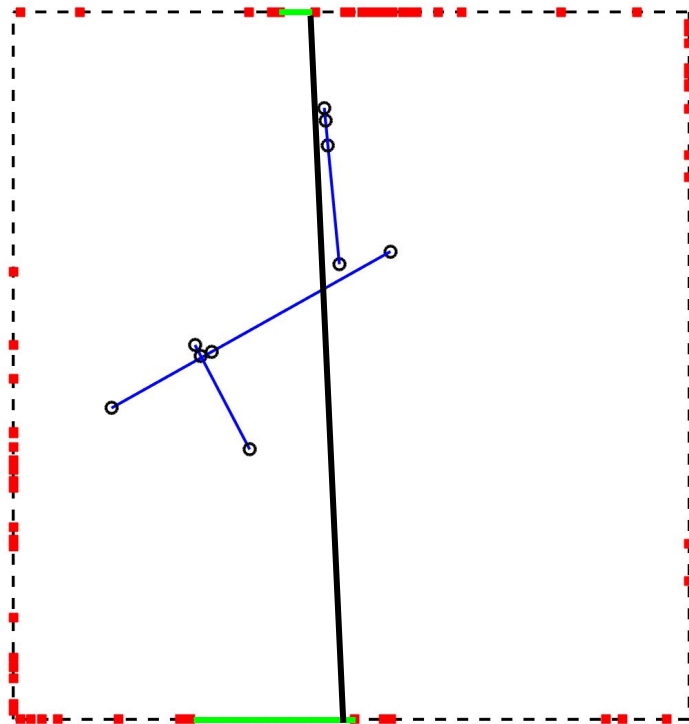
3: Find pairs of intervals with 0 M-imbalance



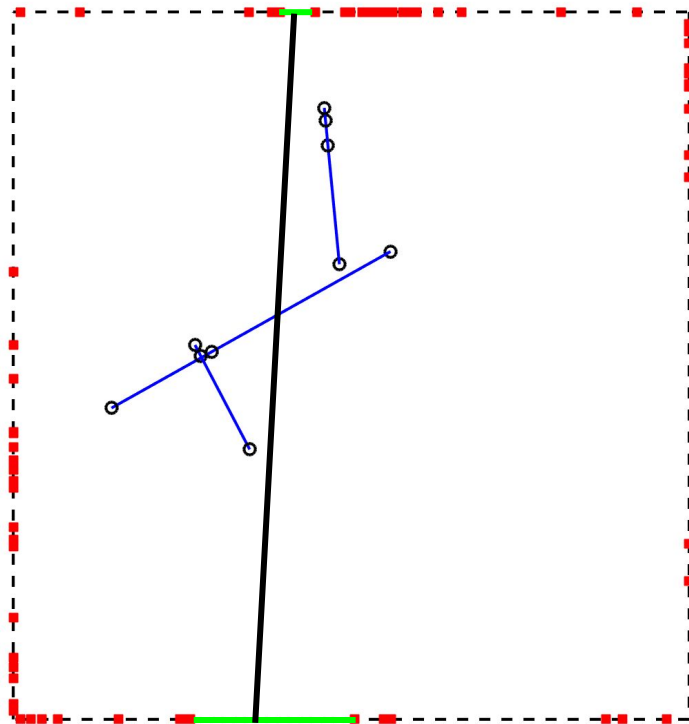
3: Find pairs of intervals with 0 M-imbalance



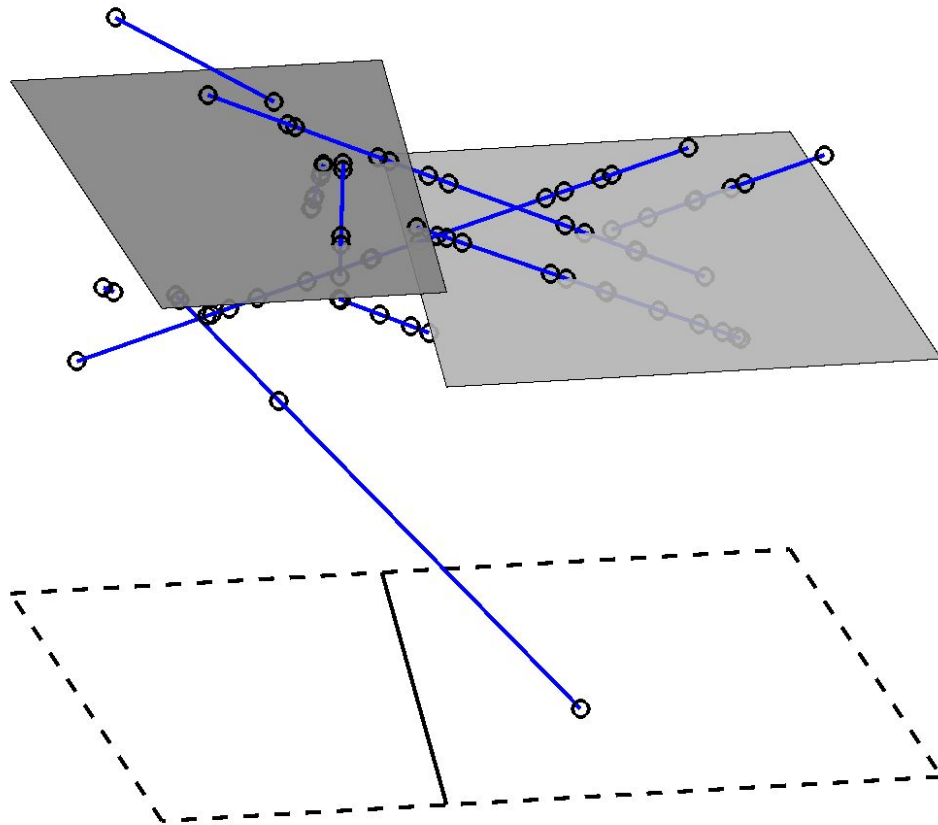
4: Look for avg-balanced splits



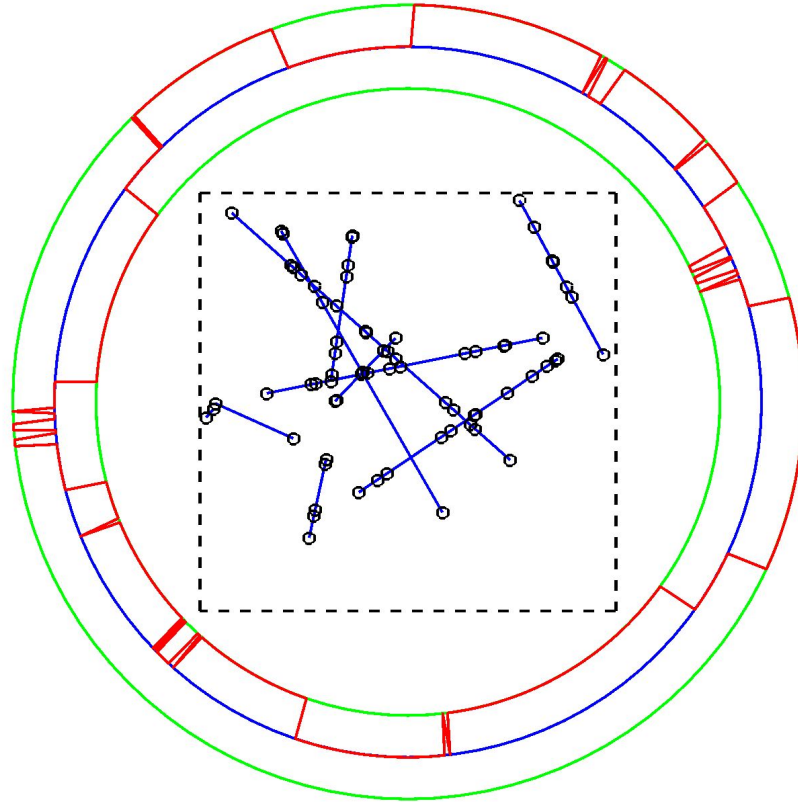
4: Look for avg-balanced splits



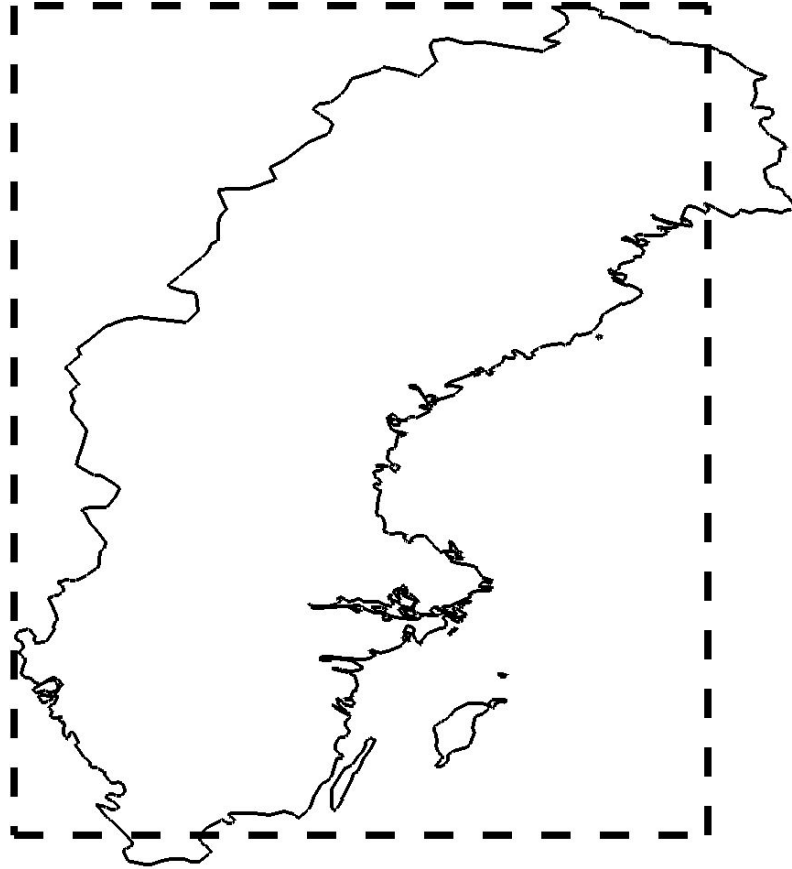
Artificial example



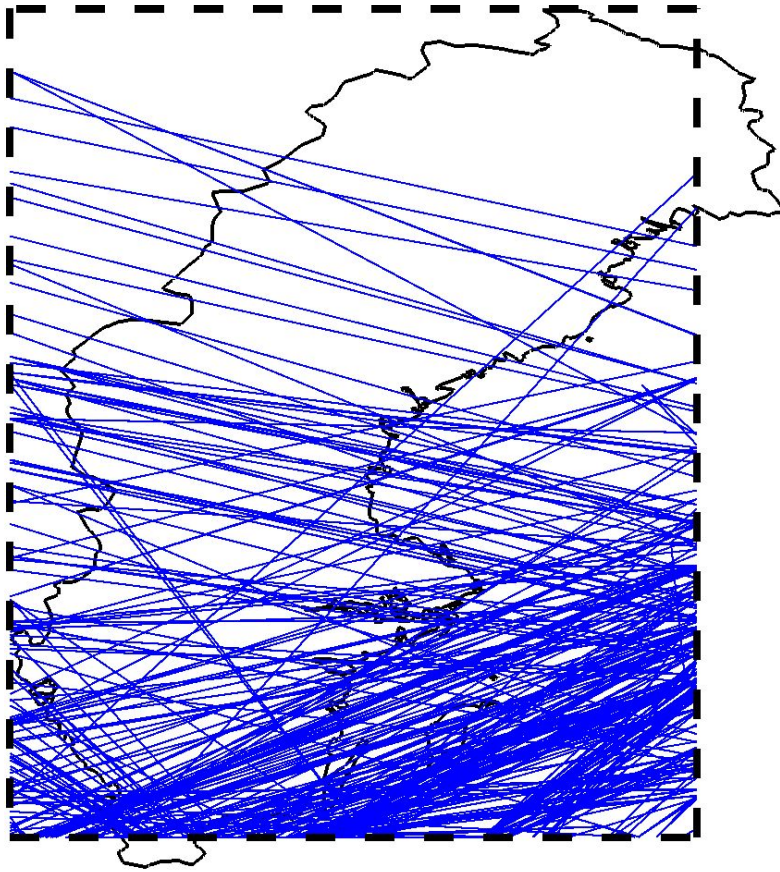
M-imbalance changes



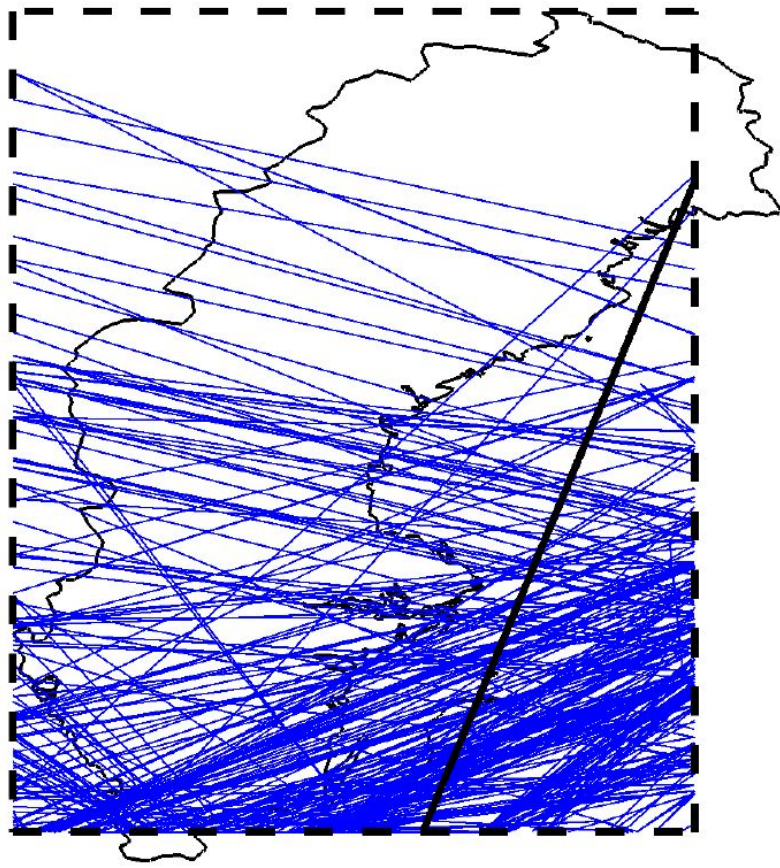
Rectangular boundary



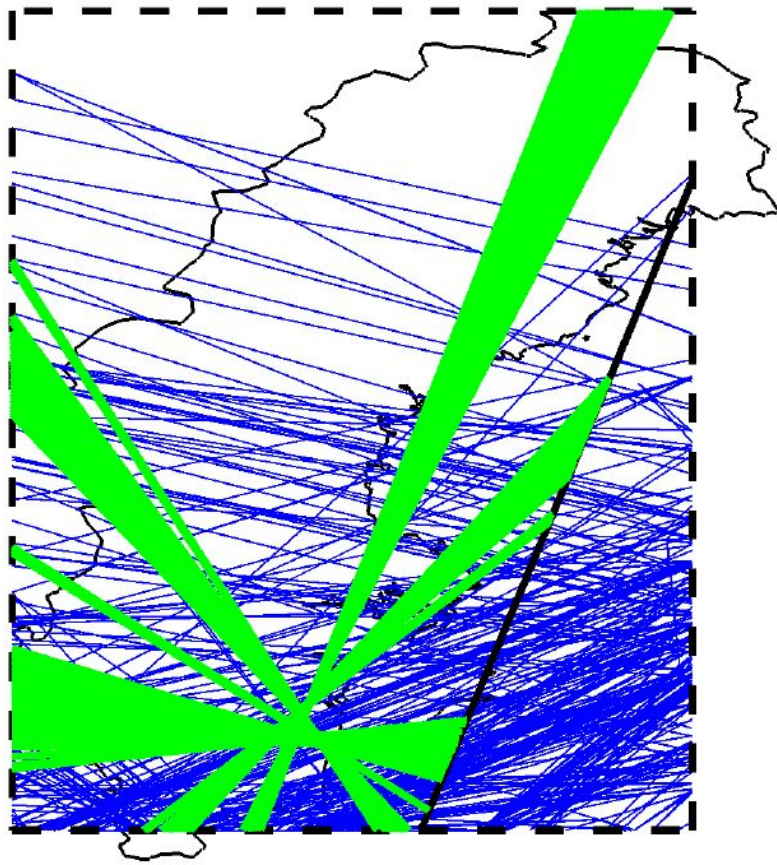
Straightline flight segments



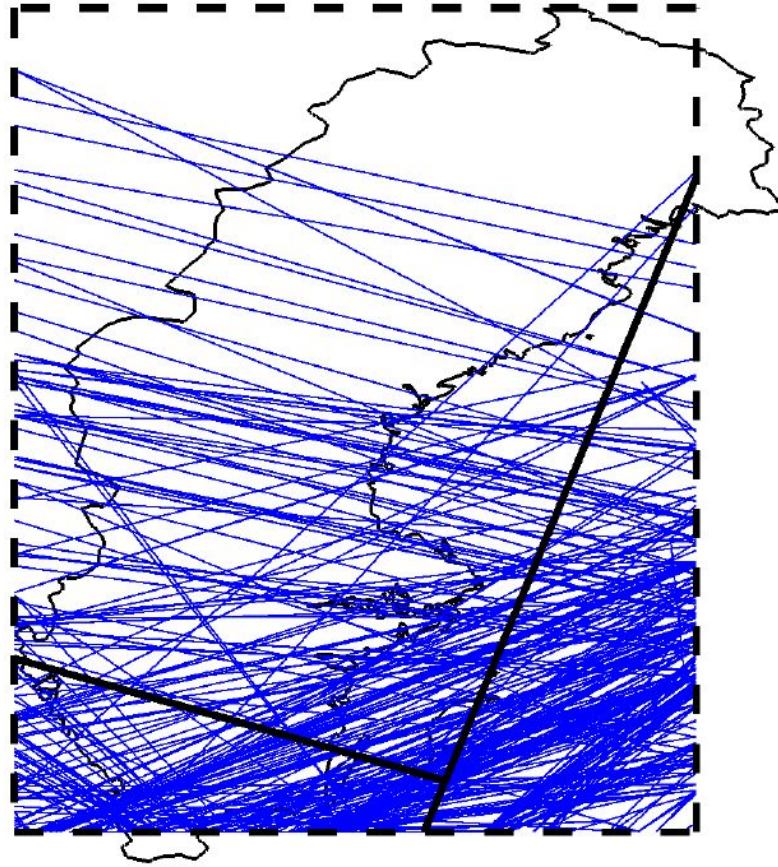
Optimal cut



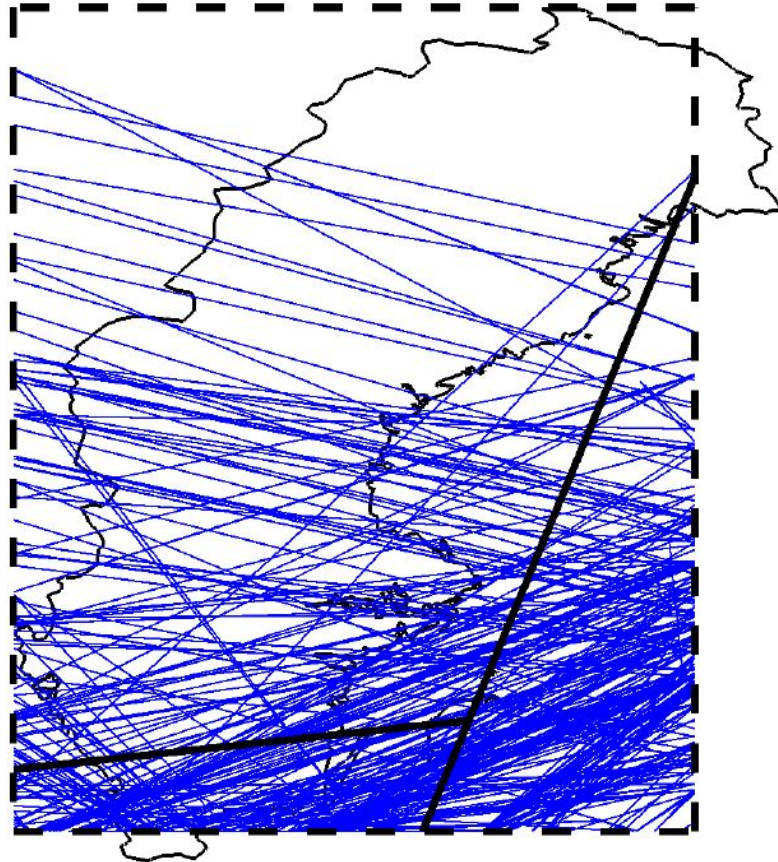
All optimal cuts



Second cut



Second cut



Further research

- Multiple sectors
 - Directions of flights
 - Interaction between flights and boundaries
-
- Choose between optimal cuts (KPI?)

Further research

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