A Method for Spatializing Disturbance by Detecting Human-Wildlife Encounters from GNSS Trajectories

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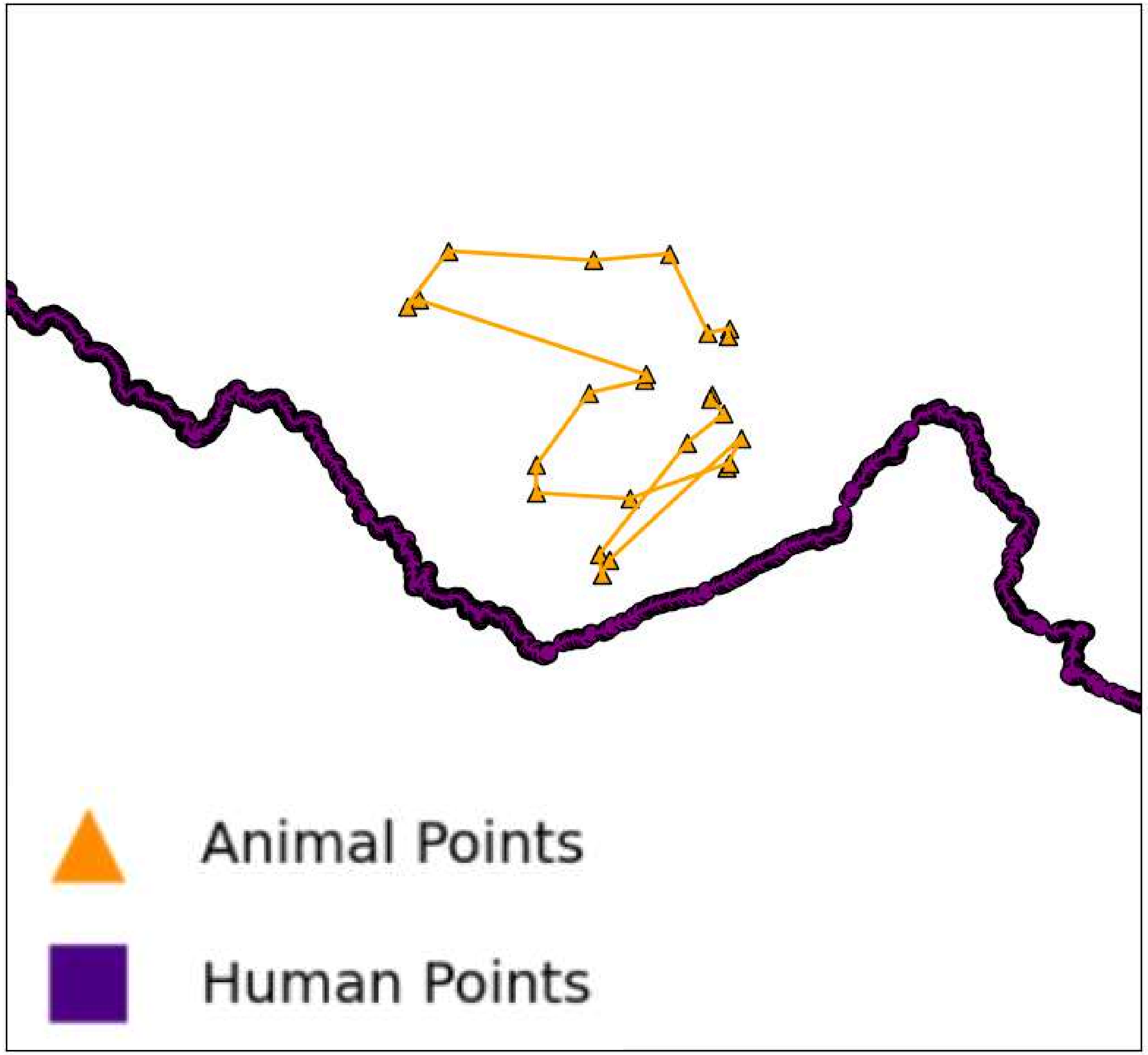
Context

- Increase in the number of humans using “wild spaces” (Balmford et al., 2015)
- Repeated interactions with humans have negative effects on wildlife
    - Increased stress levels (Stankowich, 2008)
    - Abandoning high value land (Courbin et al., 2022)
    - Time spent in alert state (Taylor and Knight, 2003)
- **Goal**
    - **To better understand the pressure on wildlife from humans**

IntForOut

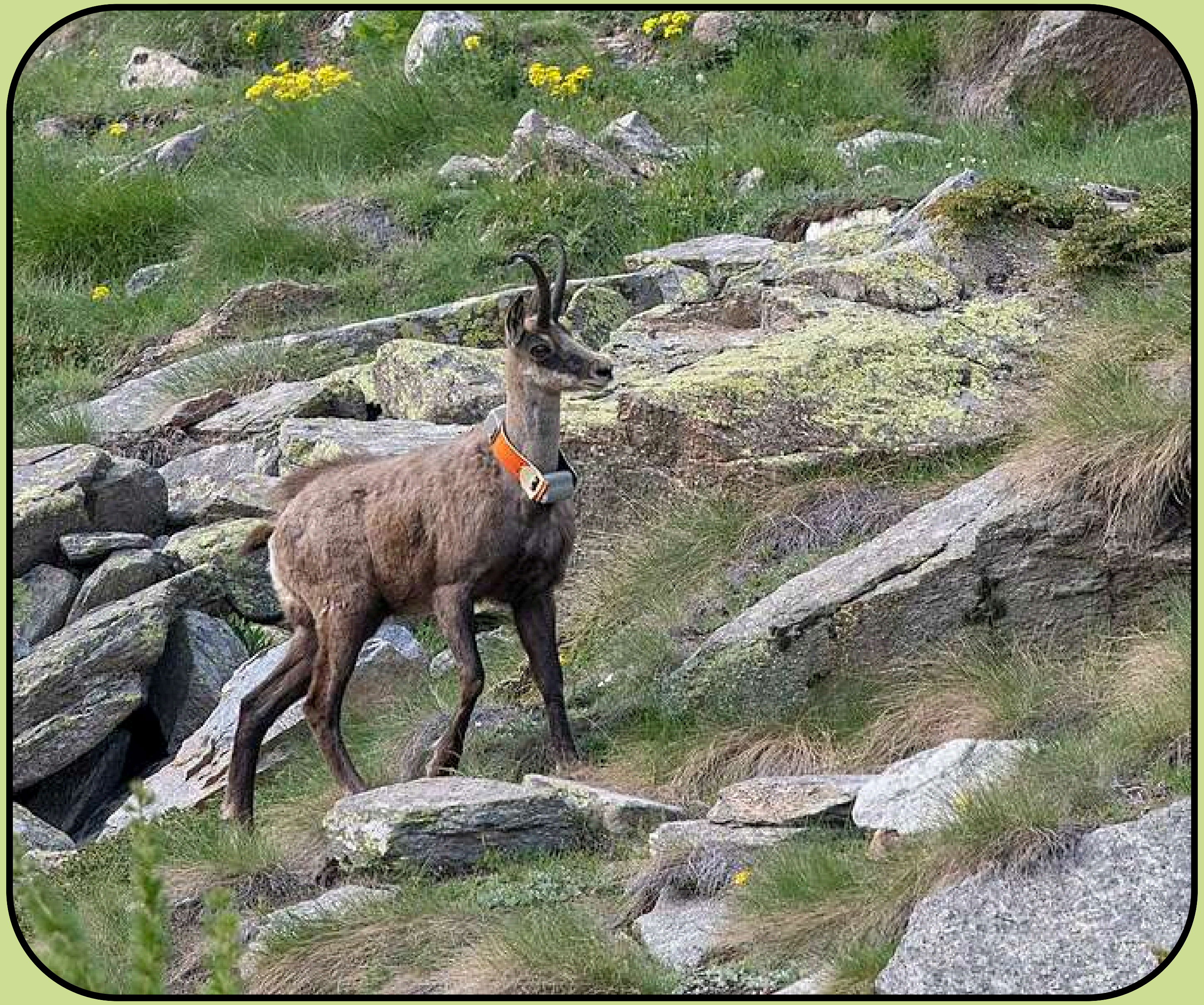
Introduction

- **Method**
  - Detect instances **where** and **when** a human's presence could have disturbed wildlife
- **Difficulties**
  - Heterogeneous data granularity especially in animal data
  - Incompleteness and distance of interaction both relevant
  - Limited data



Chamois

- Show strong site fidelity, using the same areas seasonally and yearly (Darmon et al., 2012; Duparc et al., 2019)
- Primarily use vision to detect threats (Hamr, 1988)
- Data from GPS collared animals



Core Concepts

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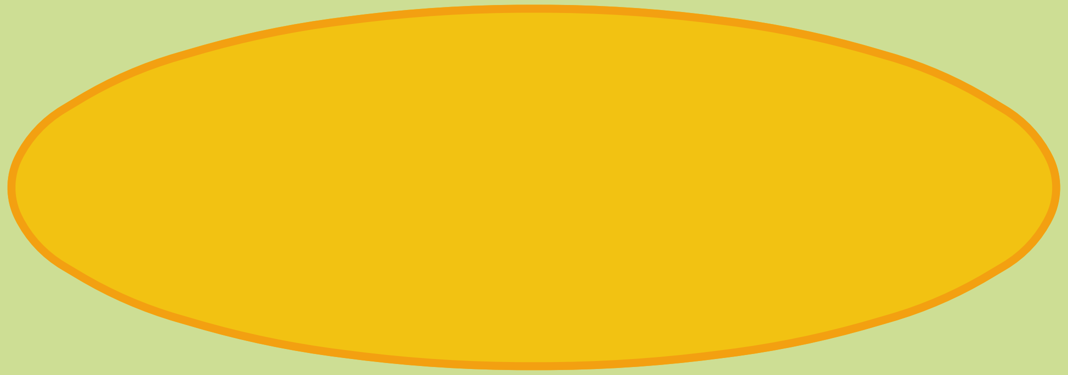
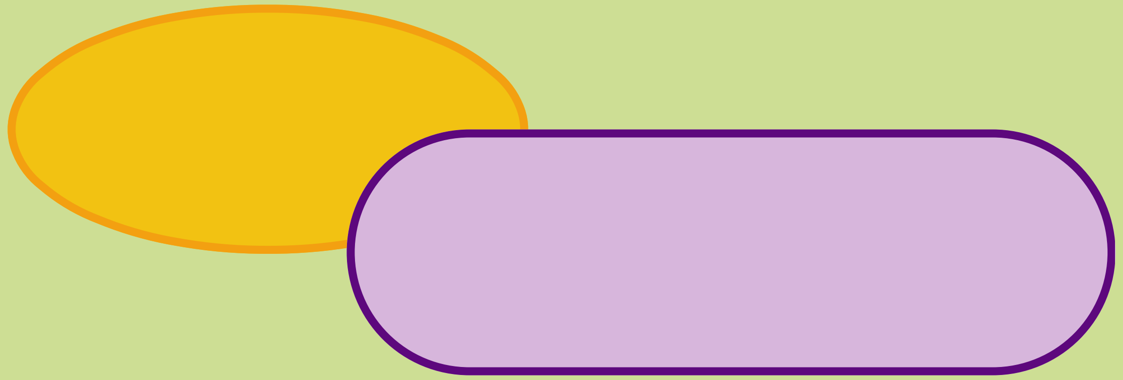
Potential Path Area (PPA)

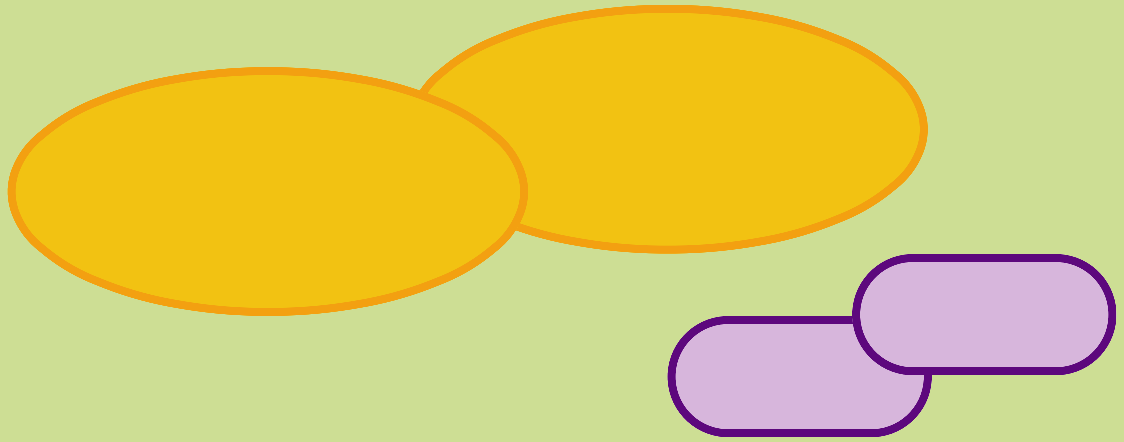


Human Disturbance Area (HDA)

Encounter Event (EE)

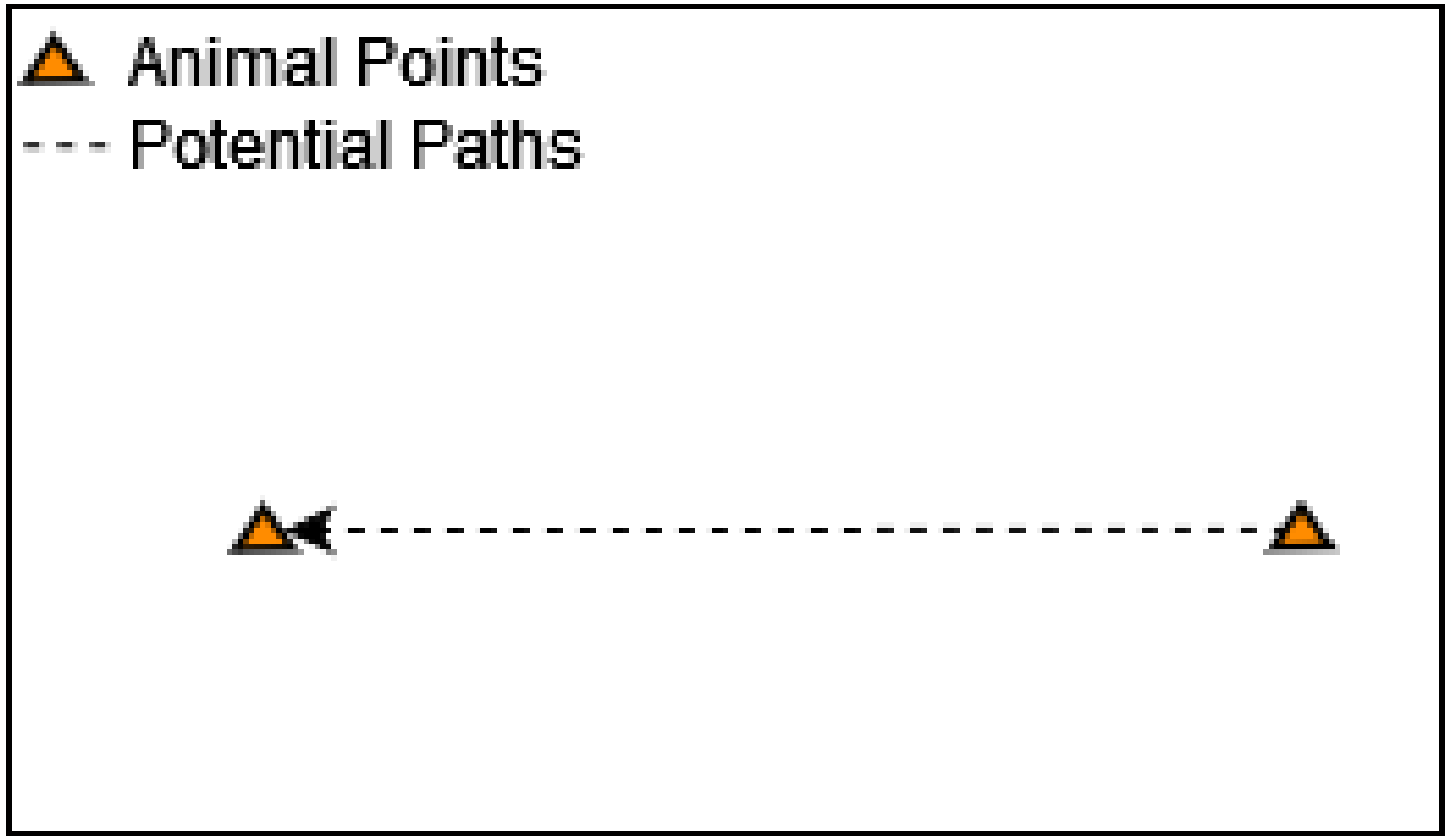


Encounter (EC)



Potential Path Area (Long et al., 2015)

- Used to estimate the possible locations a tracked object could have been in between two GPS points



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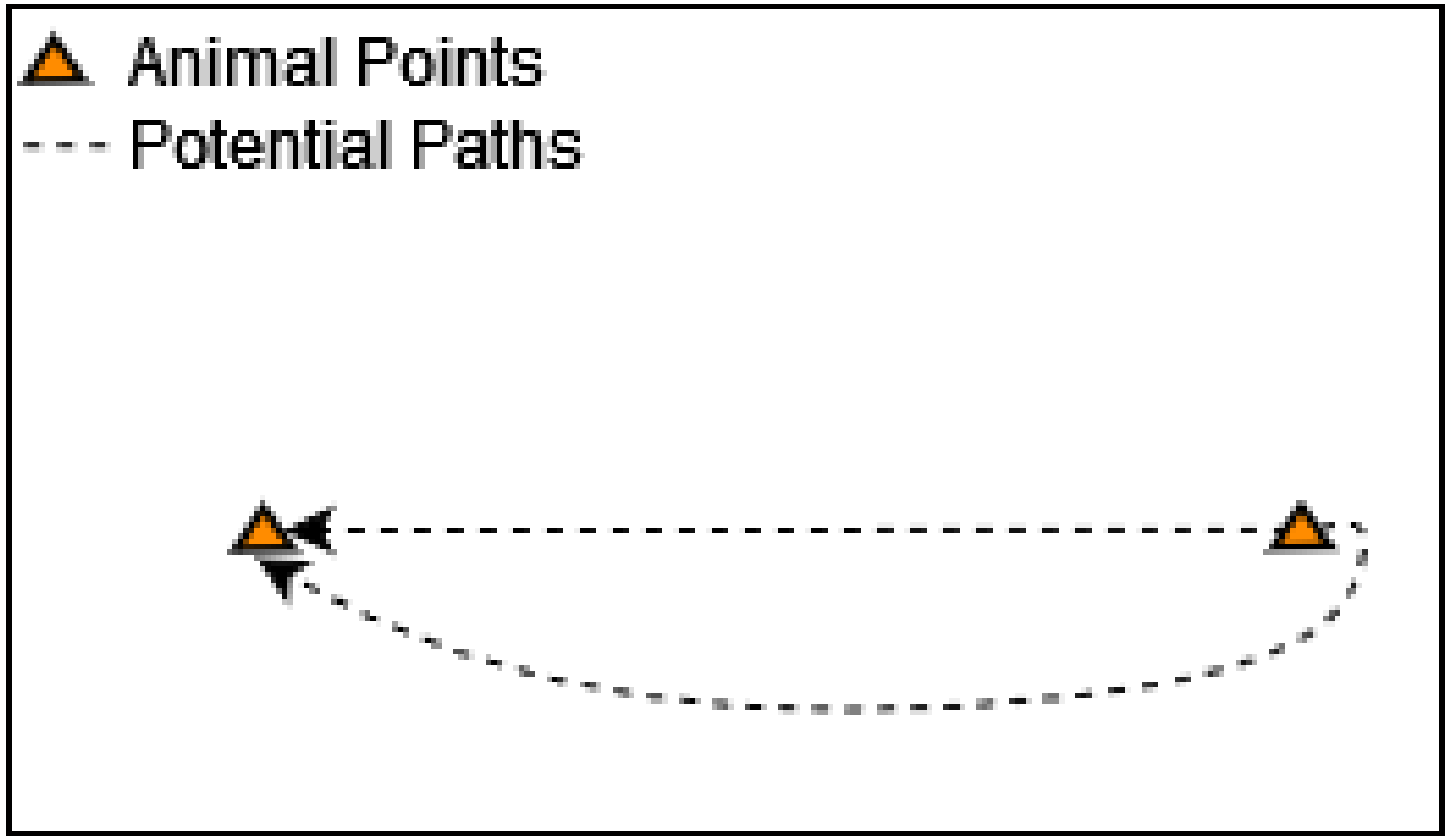

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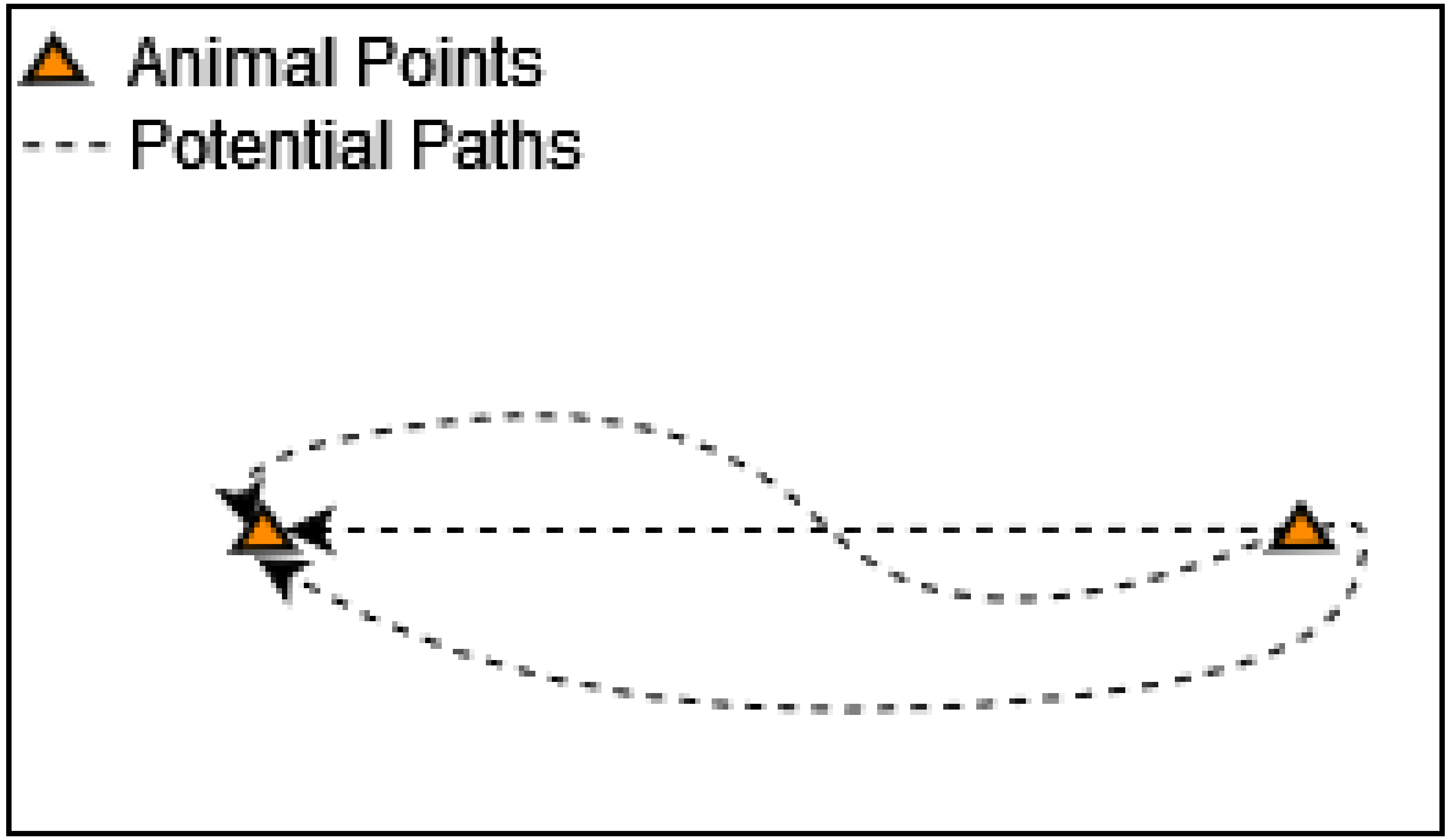

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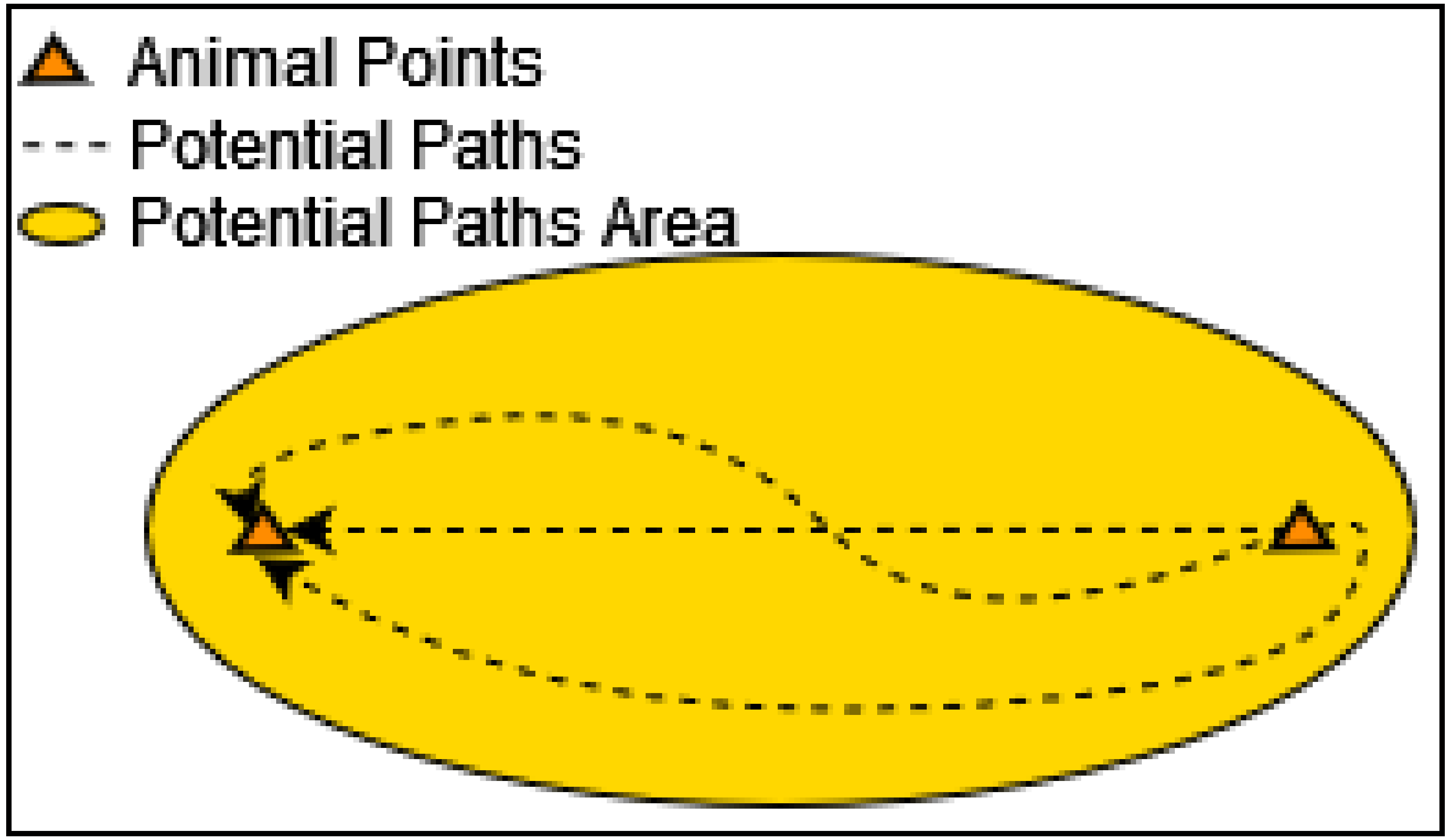

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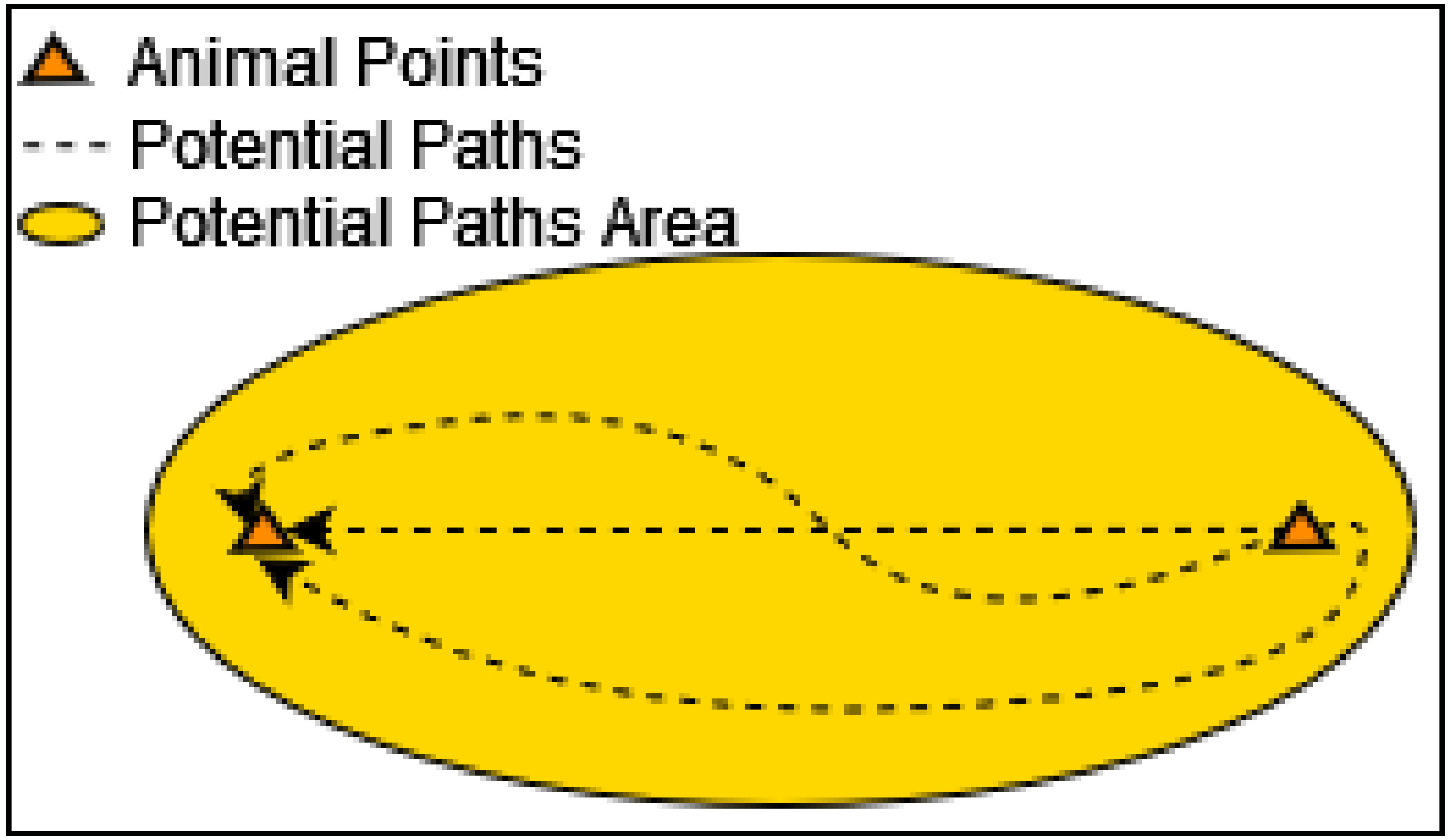
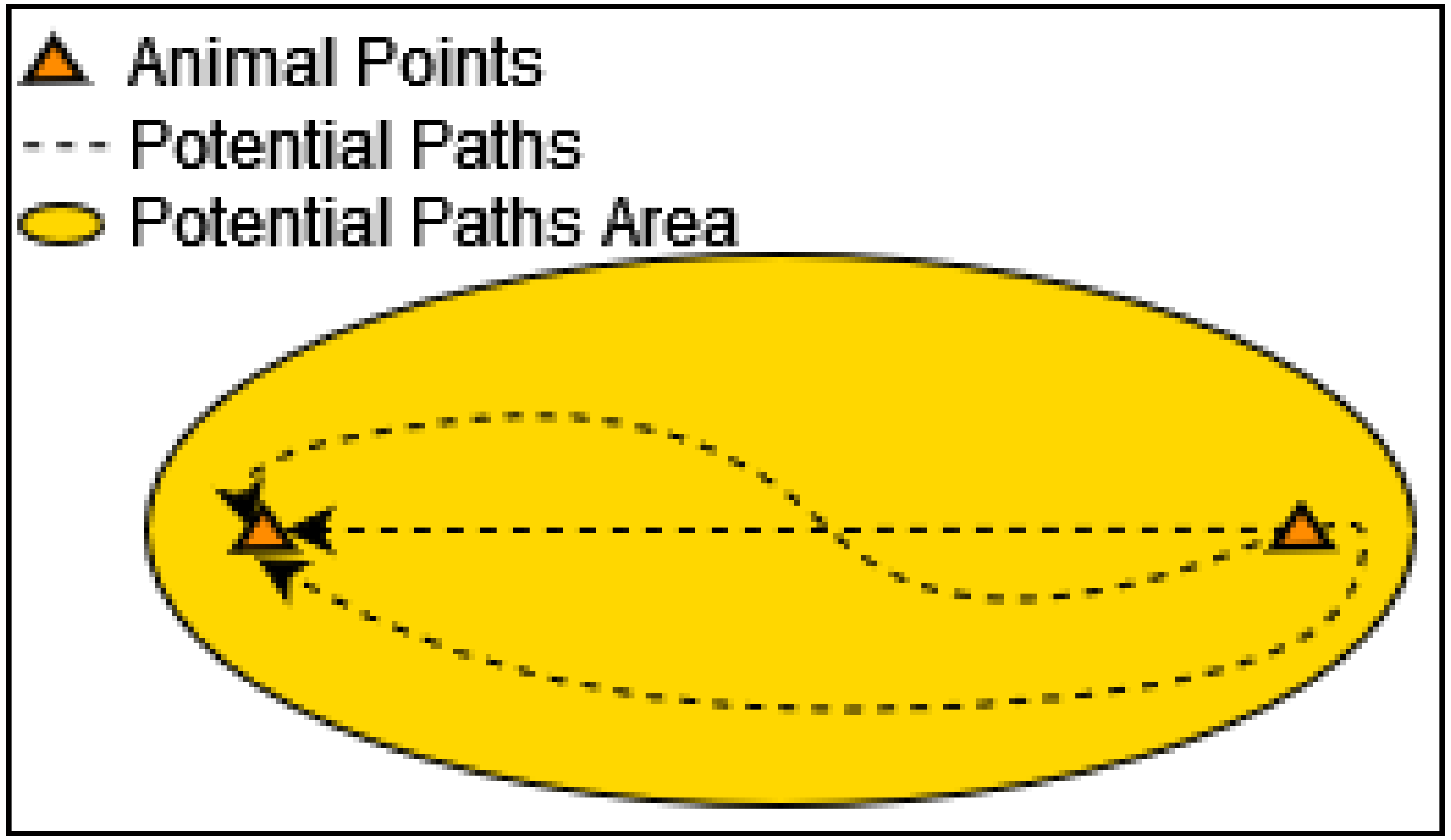


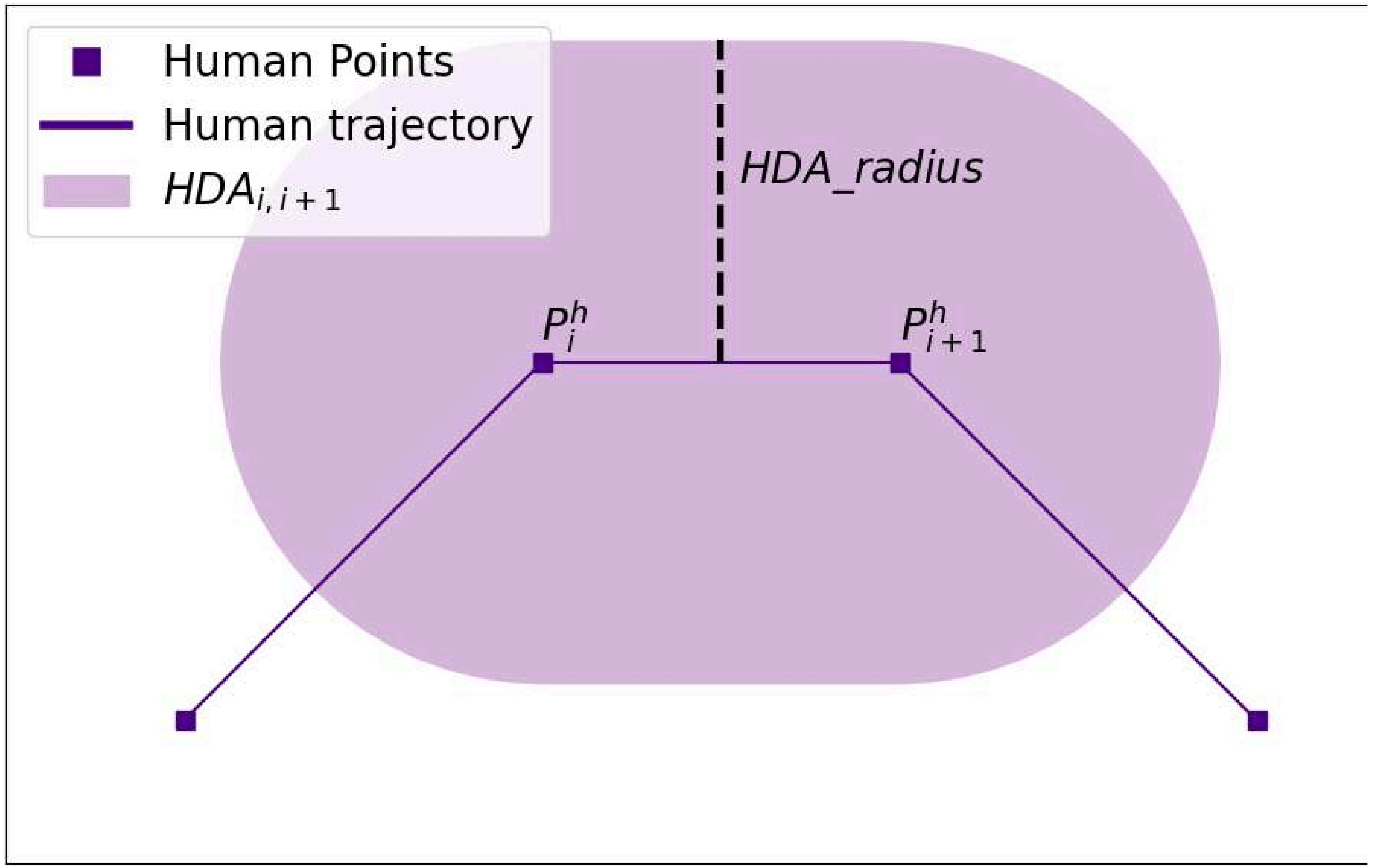
Potential Path Area (Long et al., 2015)

- Used to estimate the possible locations a tracked object could have been in between two GPS points
- Important to use if the incompleteness of the data is significant
- We used this for animals but not humans, based on data granularity



Human Disturbance Area

- Estimates the distance at which two tracked objects can affect each other



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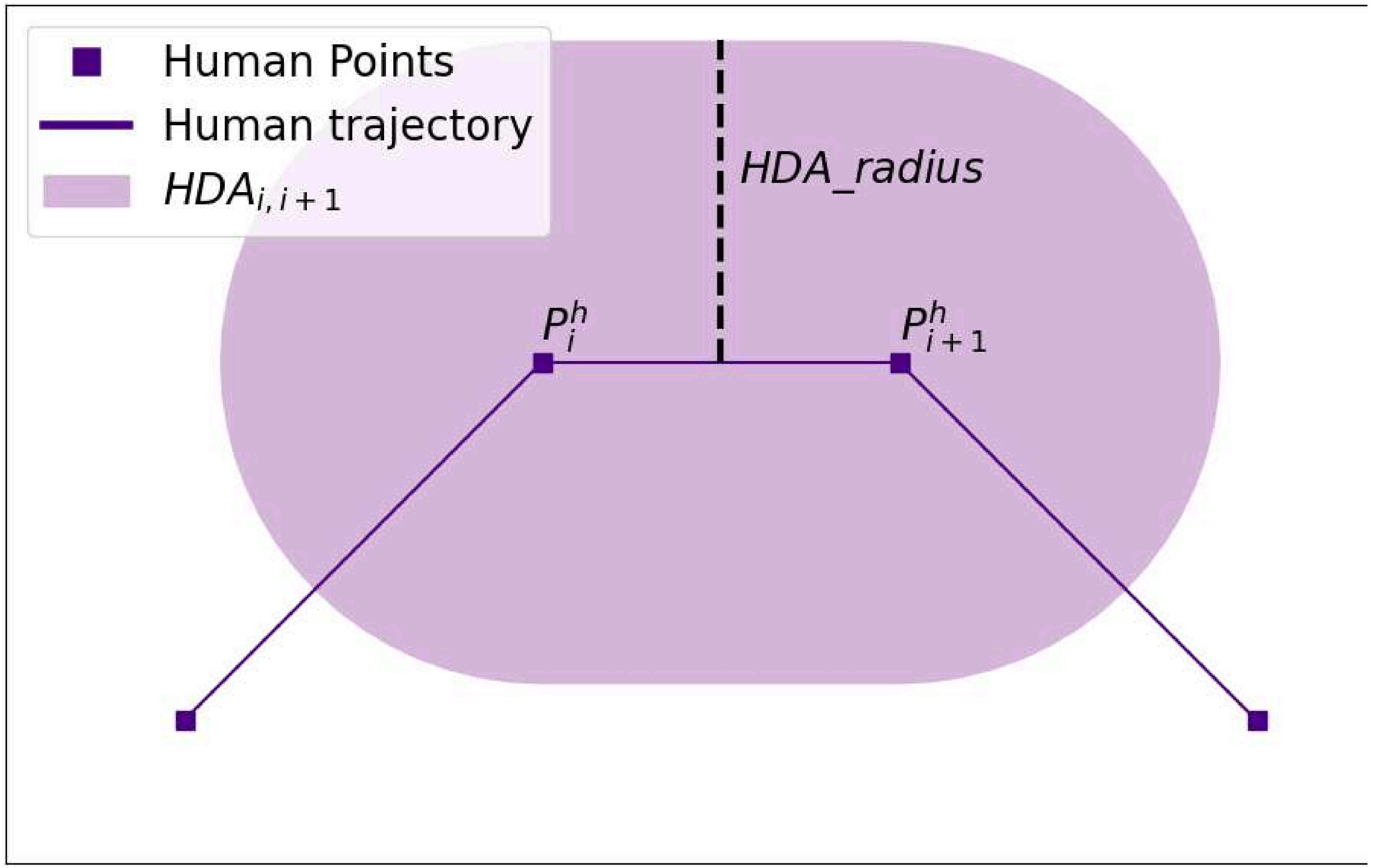
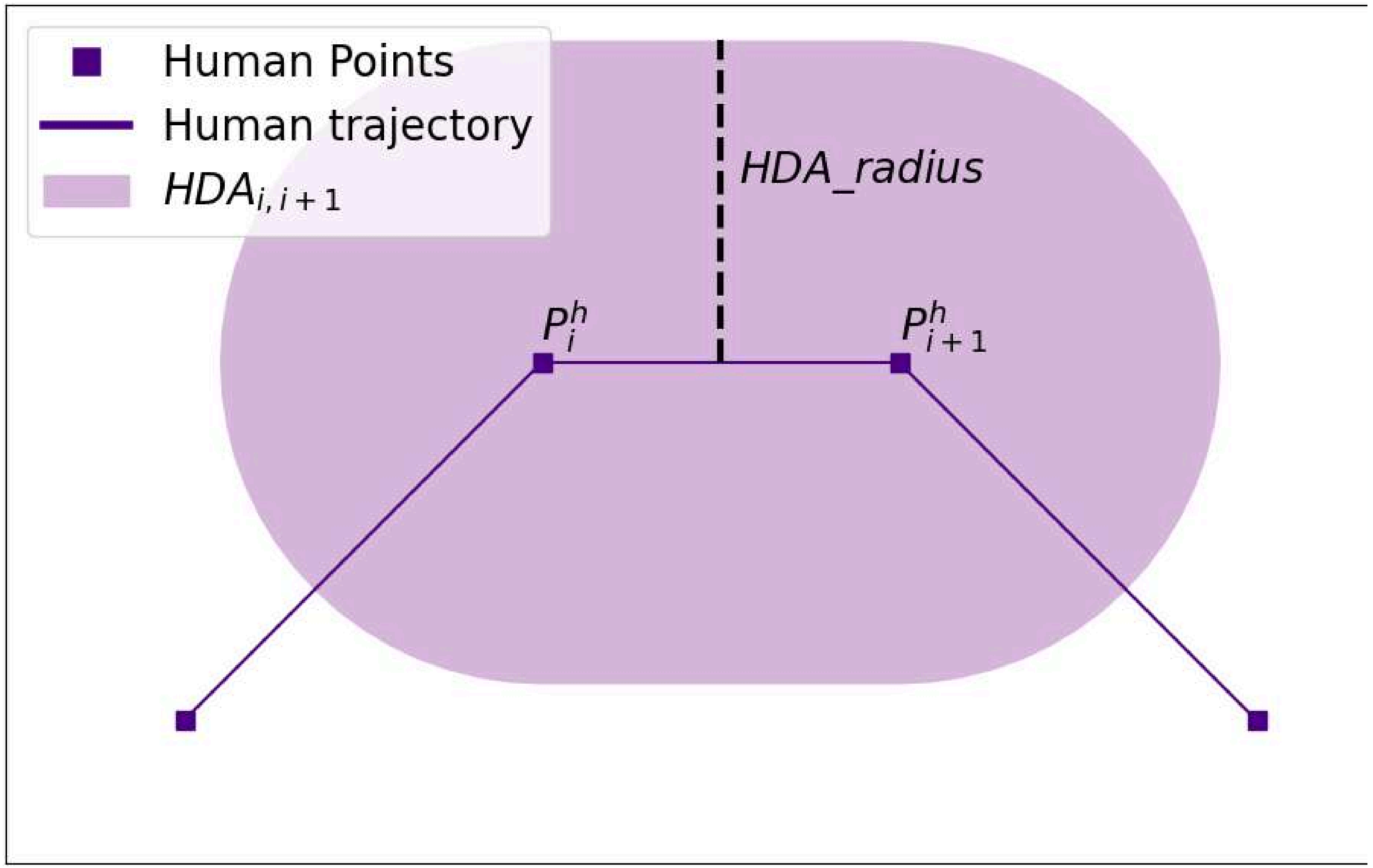
- Estimates the distance at which two tracked objects can affect each other
- Represents how close a human can approach before disturbing an animal



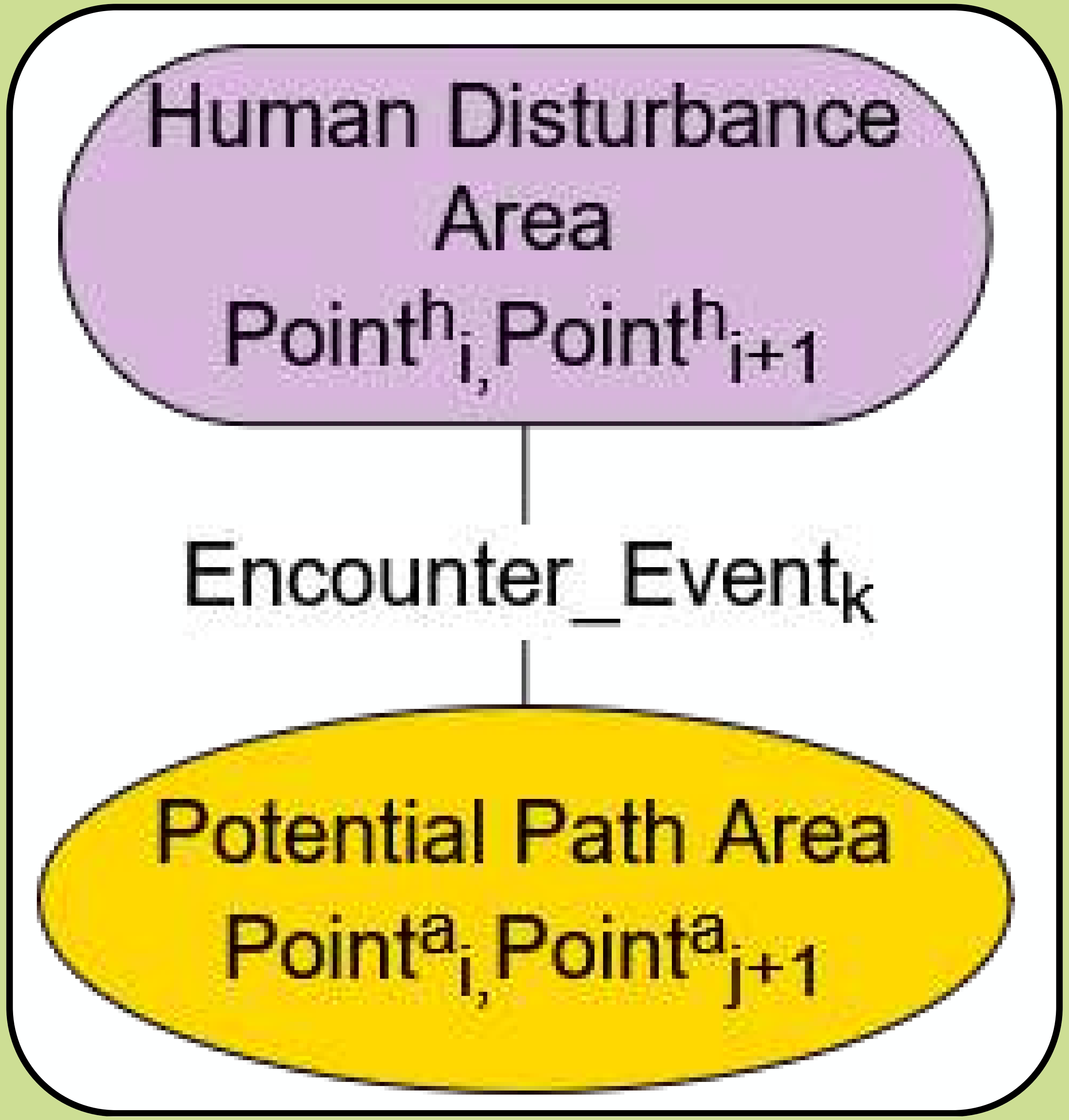
Human Disturbance Area

- Estimates the distance at which two tracked objects can affect each other
- Represents how close a human can approach before disturbing an animal
- Important to use when the distance of affect is significant



Encounter Event

- An EE is a spatio-temporal co-occurrence where a human likely disturbed an animal



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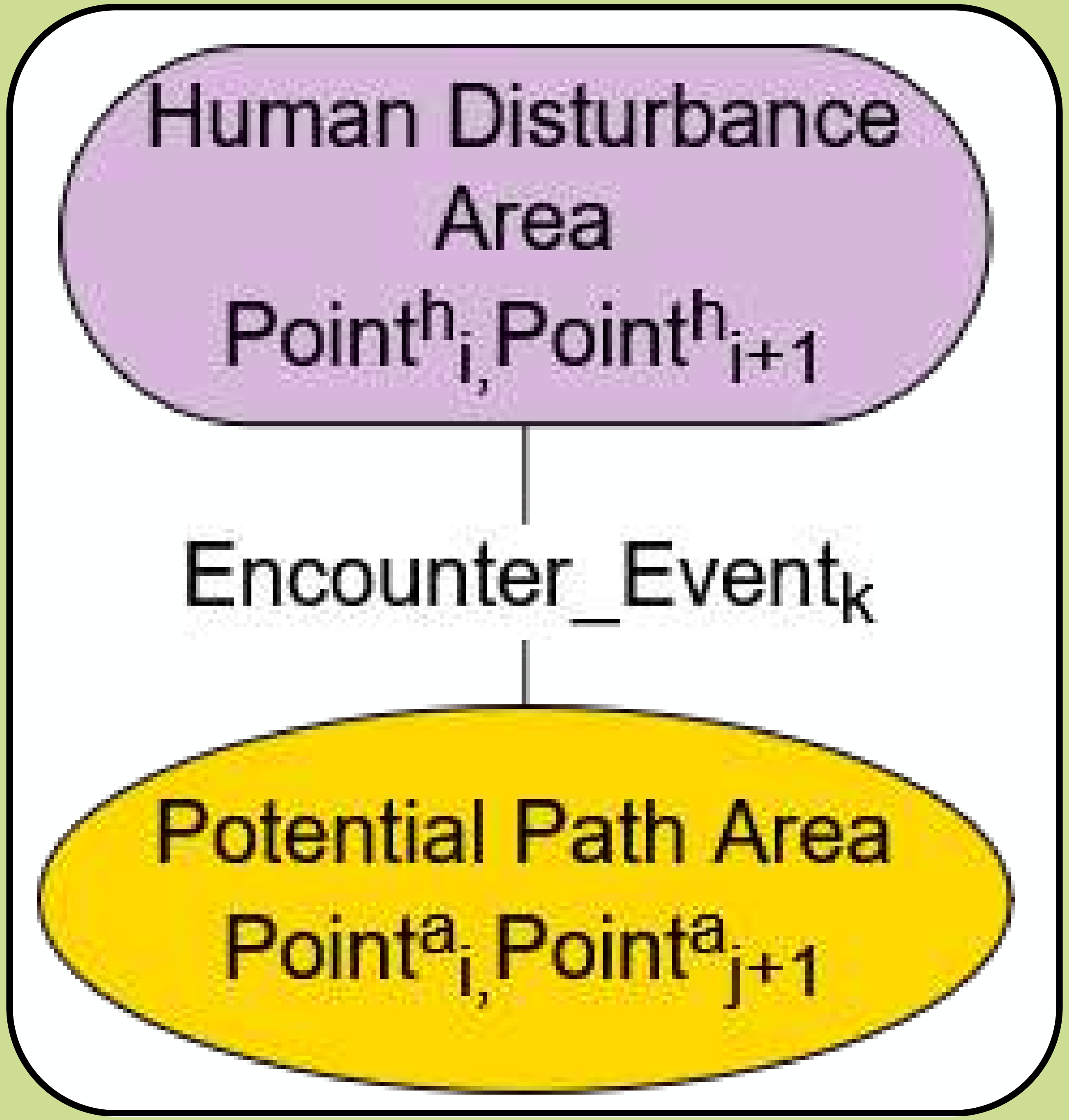

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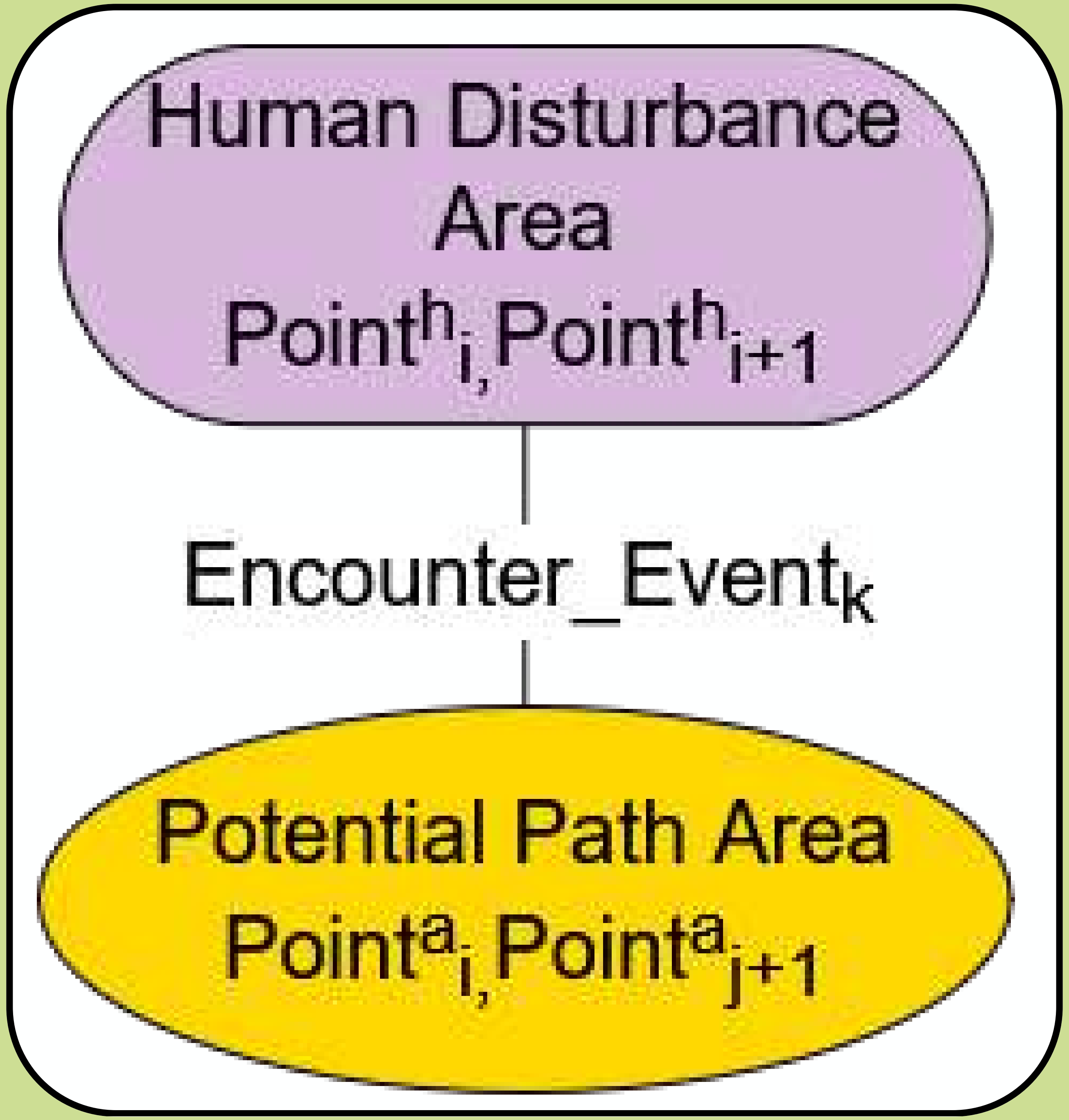
    - End points of PPA and HDA



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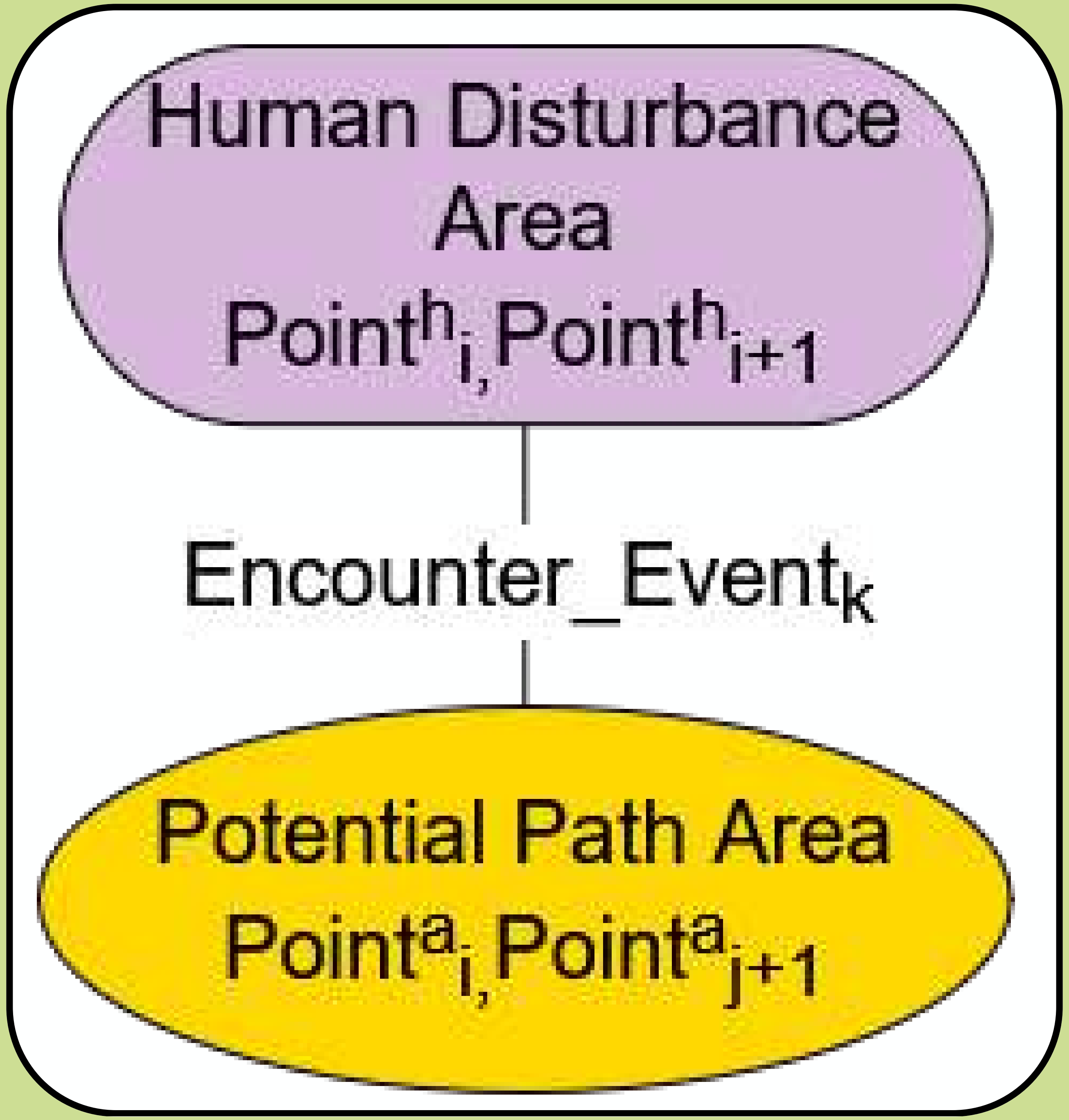
- Has 4 constraints



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- There is temporal intersection between them
- Only clock time (e.g. 15:35)

$$[time(P_i^h), time(P_{i+1}^h)] \cap [time(P_j^a), time(P_{j+1}^a)] \neq \emptyset$$

Encounter Event Constraints

1.) Spatial

- A huma… n spatial… behavi…

HDA_i … $e(P^a_{j+1})] \neq \emptyset$

Potential encounter

- To account for unrecorded trajectories
- Compare human animal trajectories that took place close in day of the year
  - (April 1st compared to April 2nd)

Real encounter

- If trajectories take place on the same date

Encounter Event Constraints

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$$\left|doy(P_i^h) - doy(P_j^a)\right| \leq doy\_shift$$

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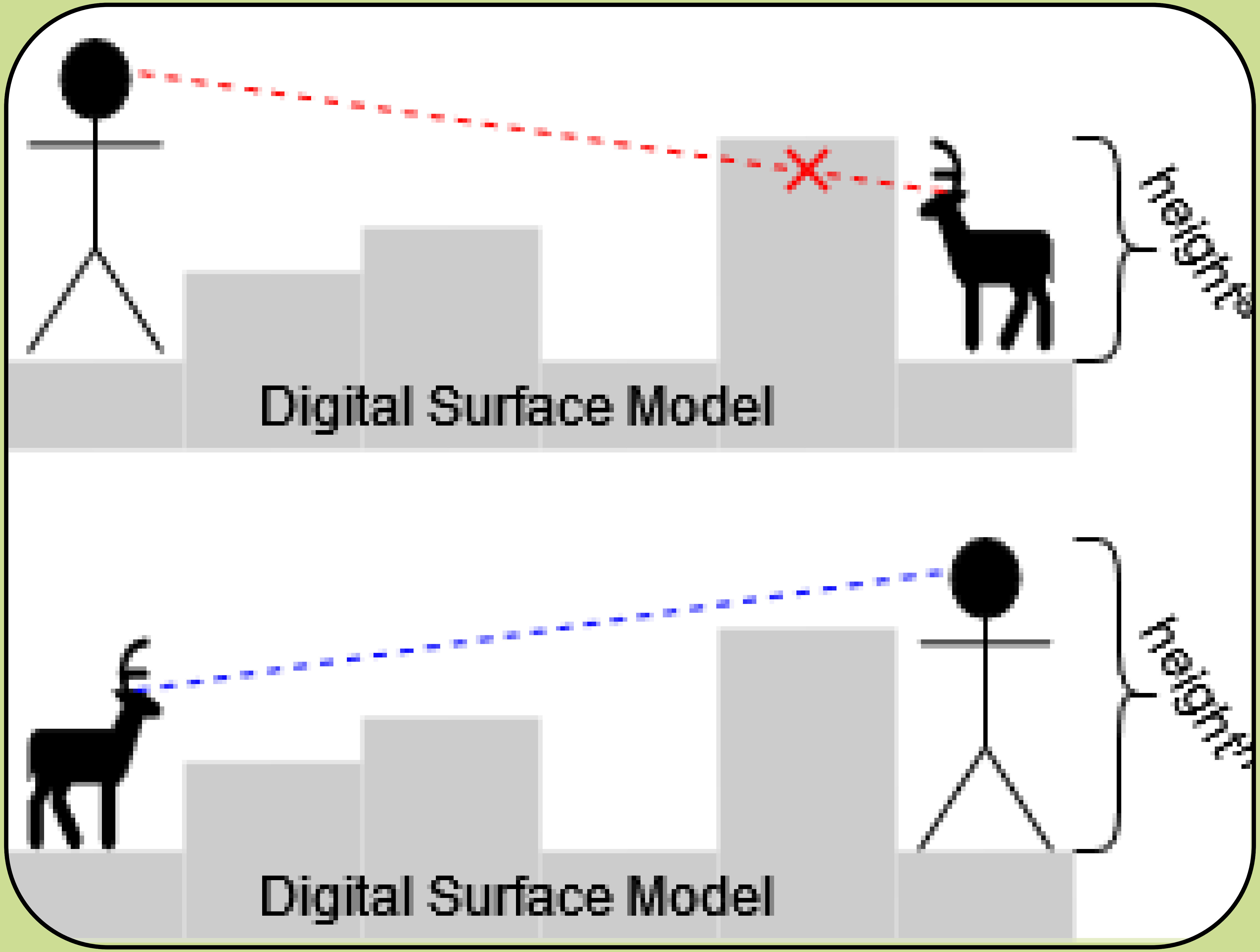
4.) Obstacle constraint

- No obstacle is preventing the human from disturbing the animal

$$\Omega(HDA_{i,i+1}, PPA_{j,j+1}) = \emptyset$$

Intervisibility



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Encounters

- Instance where human presence may have affected an animal's behavior
- Is a temporally-close set of EE

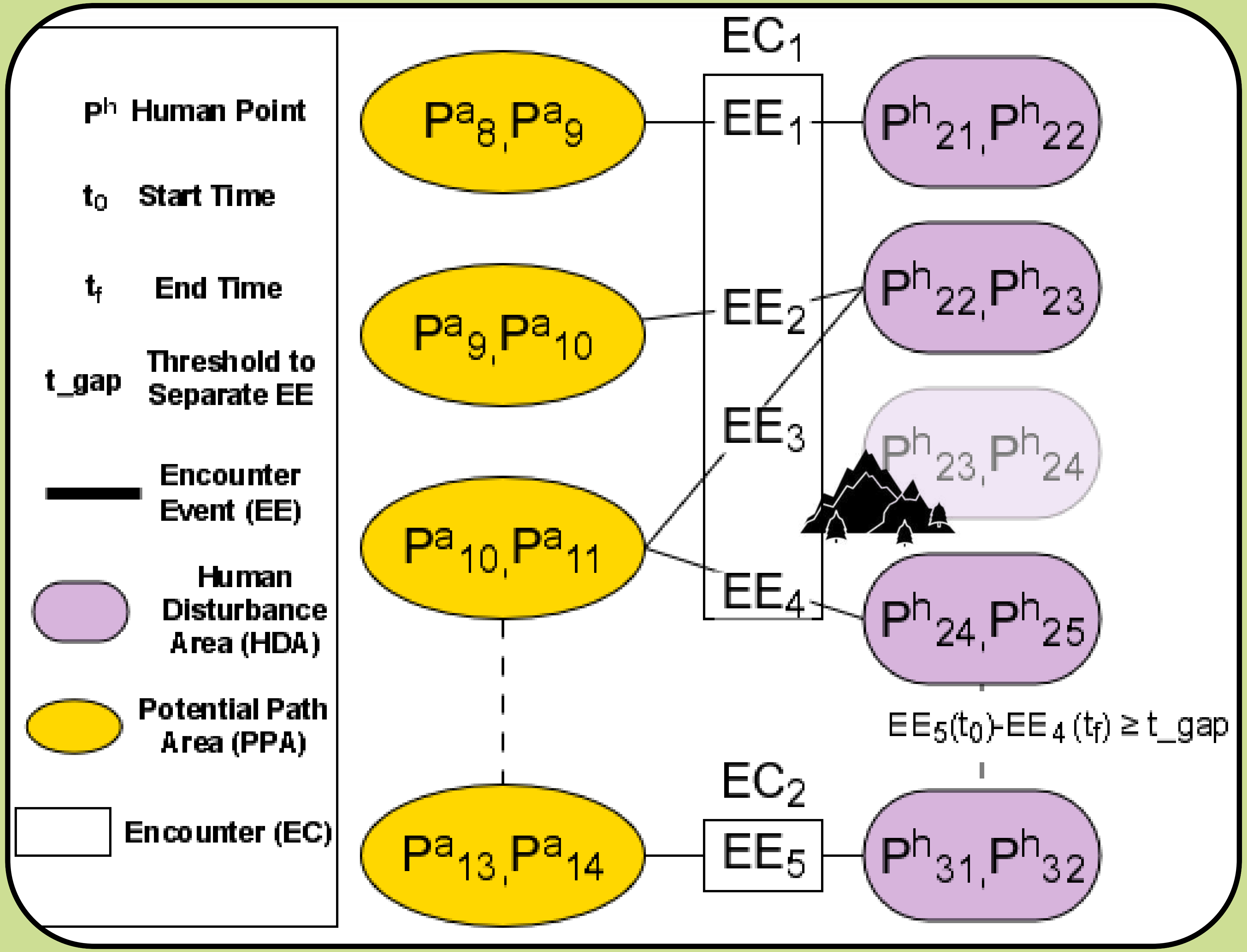
$$EC = < EE_1, EE_2, \ldots, EE_n >$$

where

$$EE_{k+1}(t_0) - EE_k(t_f) < t\_gap$$

for

$$1 \leq k \leq n-1$$



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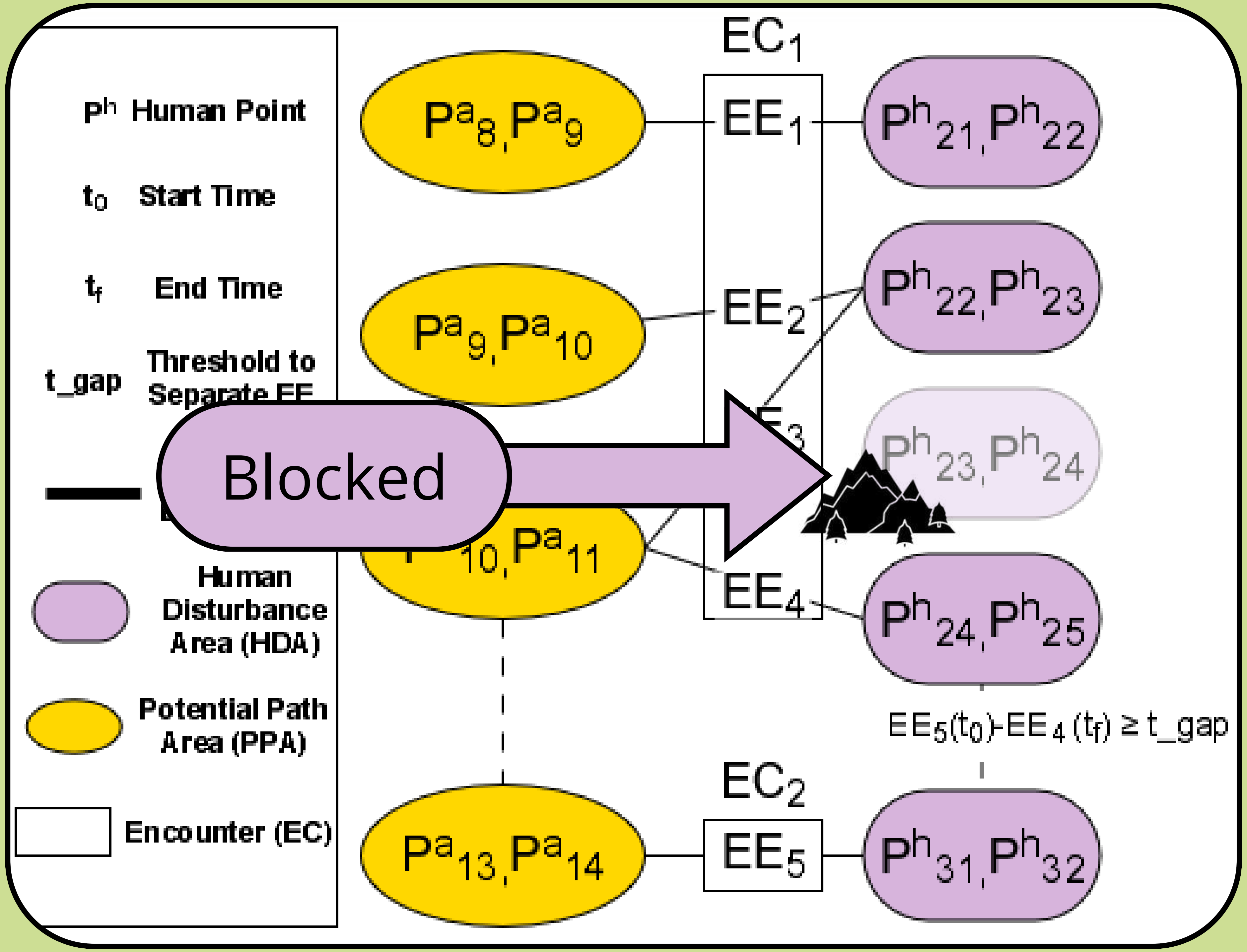

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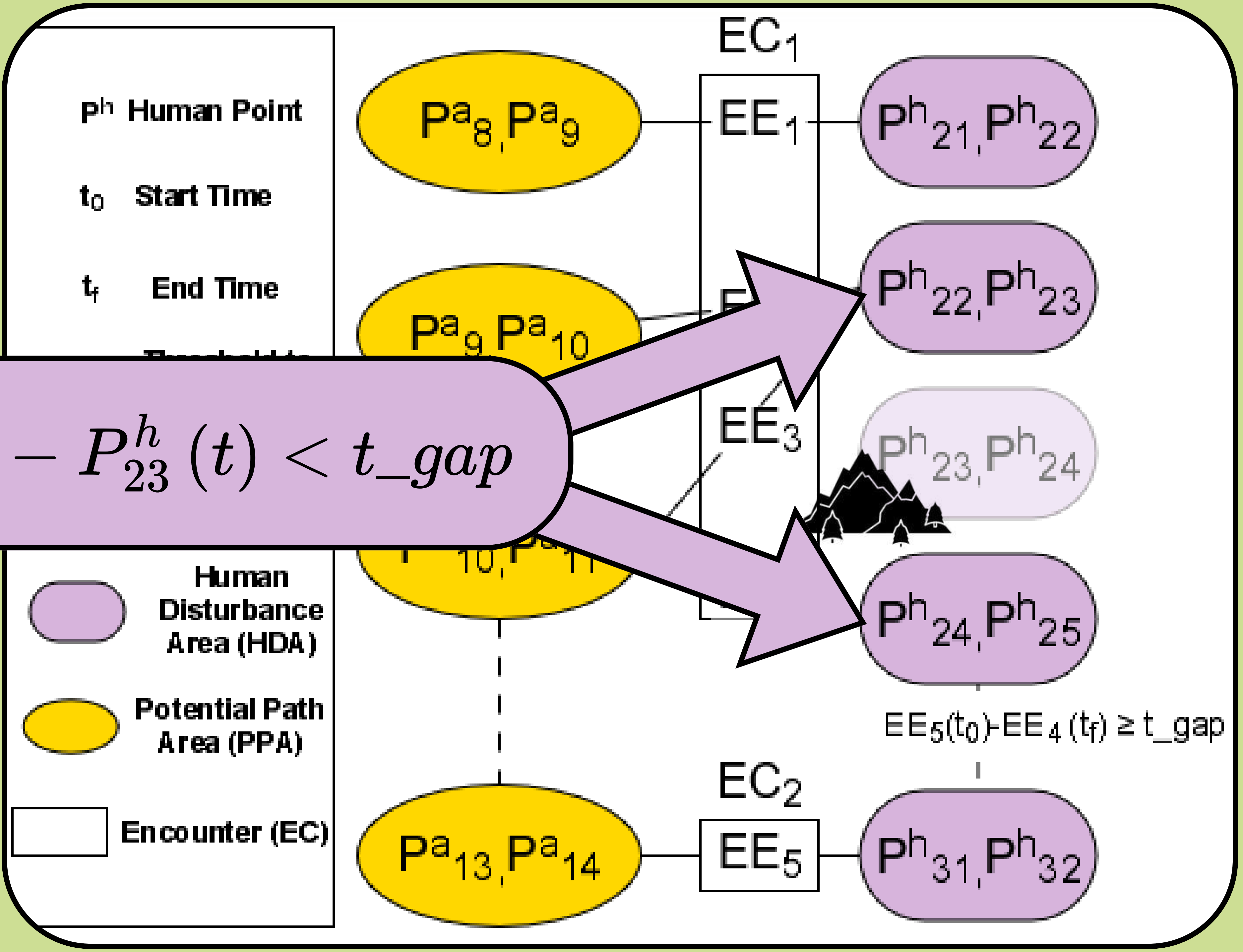
$$P^h{}_{24}\,(t) - P^h_{23}\,(t) < t\_gap$$



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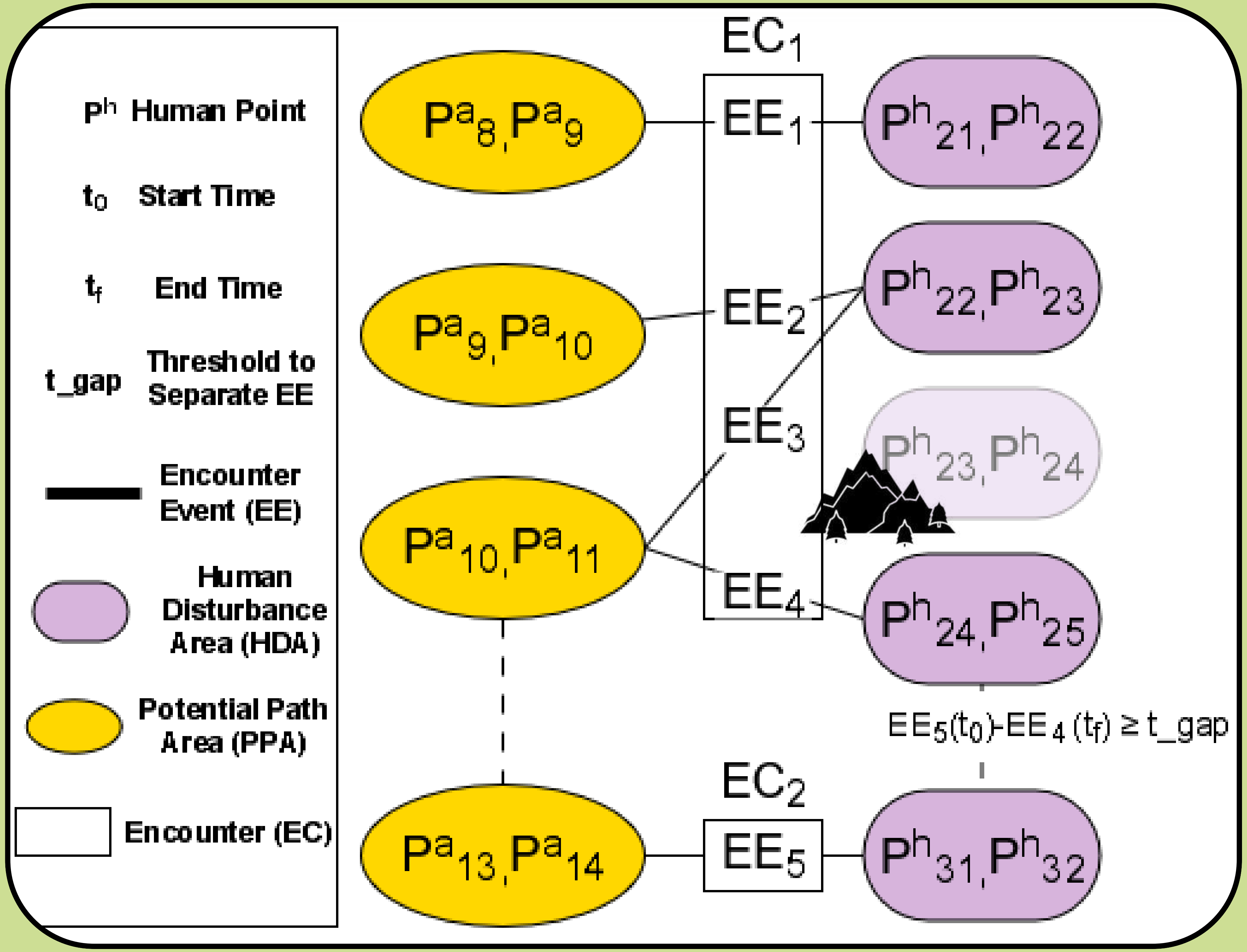

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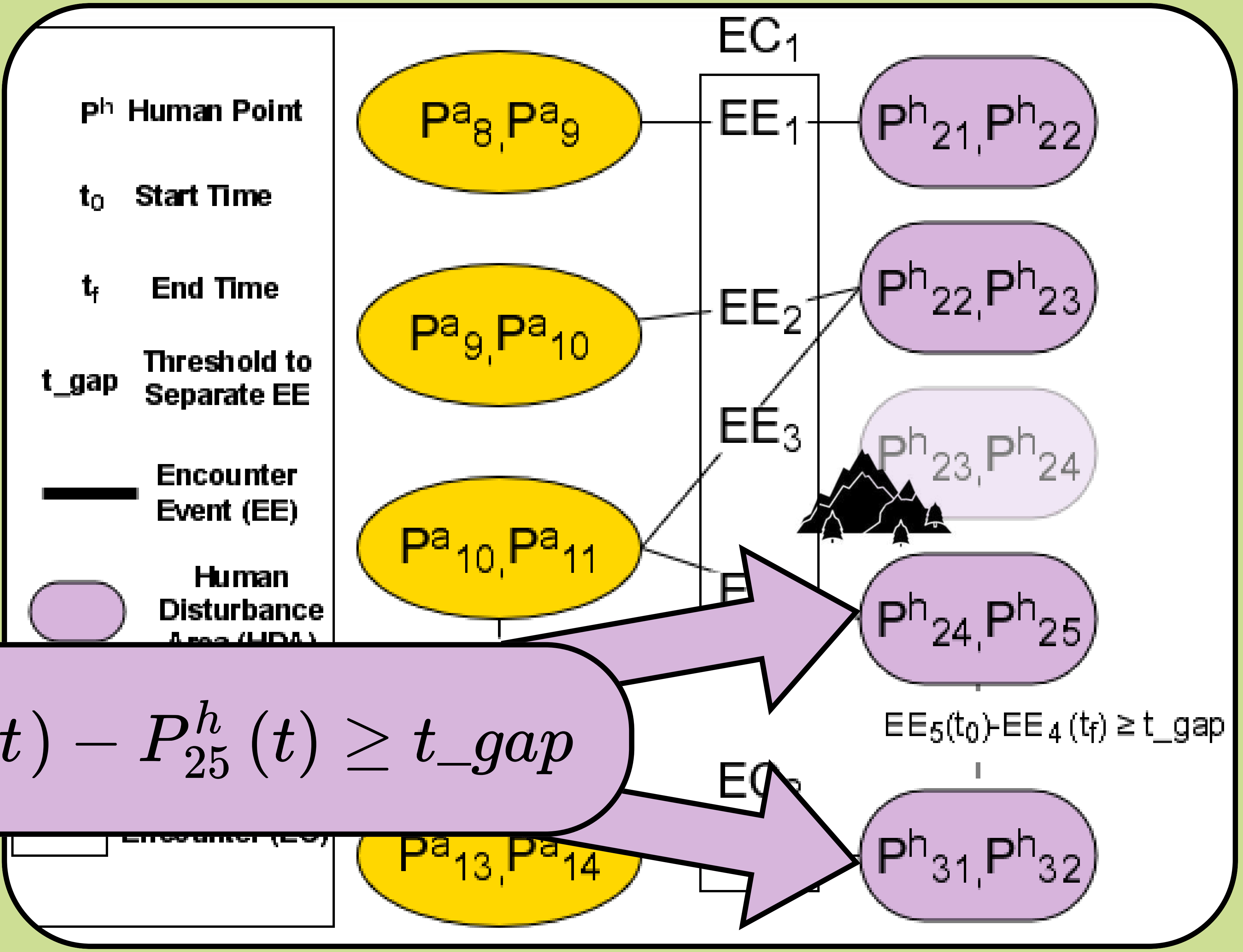

$$P^h{}_{31}\left(t\right) - P^h_{25}\left(t\right) \geq t\_gap$$

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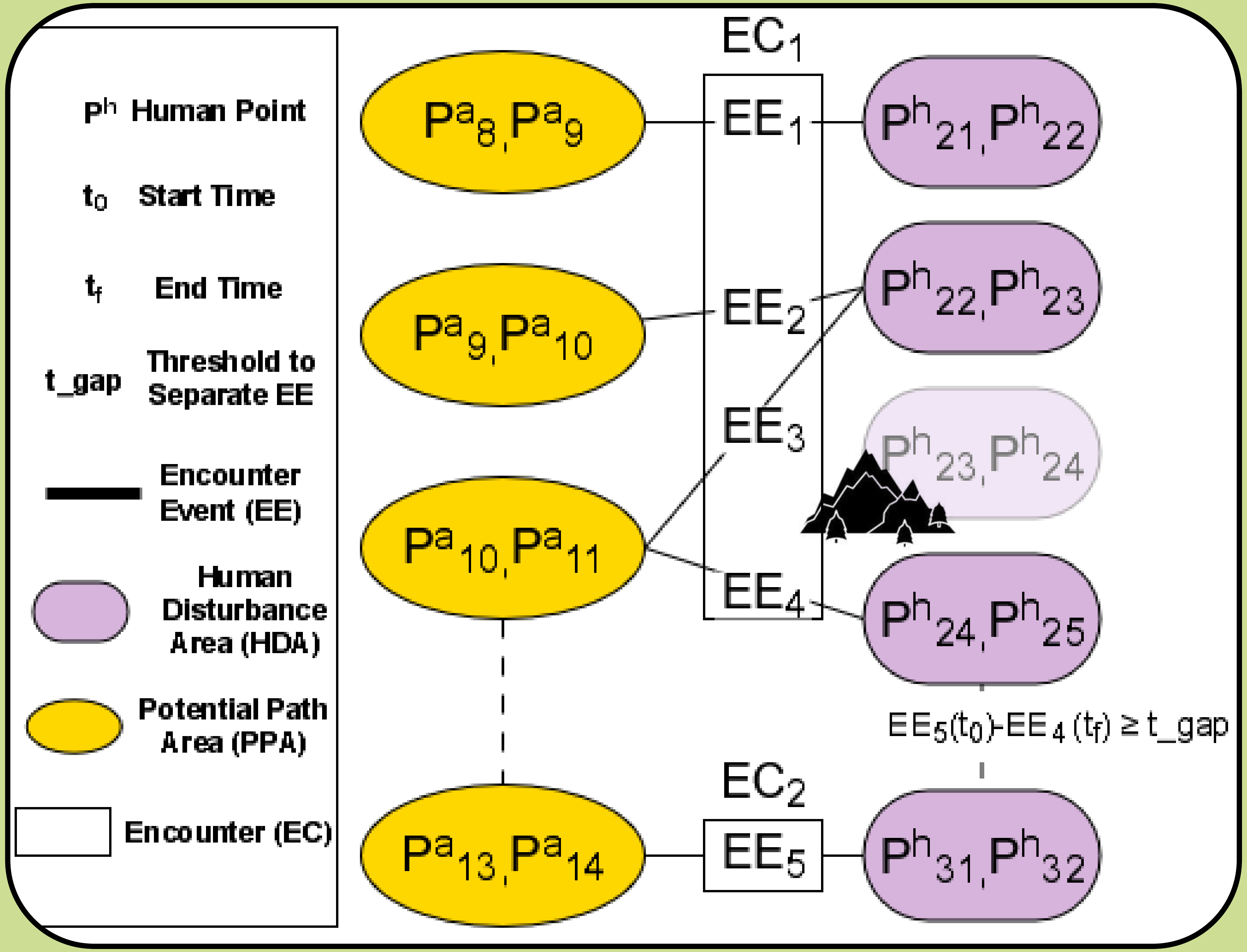

Encounters

- Instance where human presence may have affected an animal's behavior
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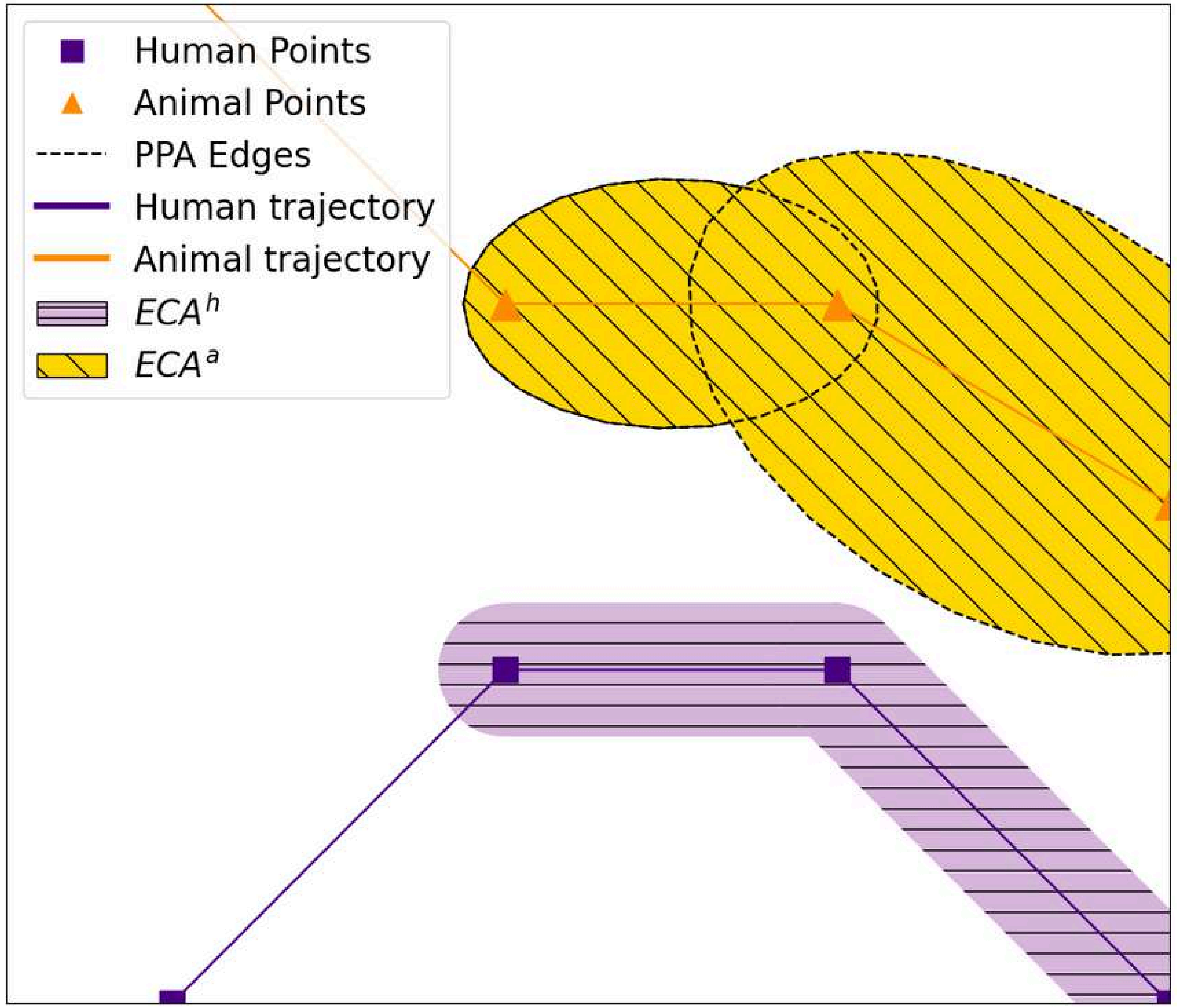
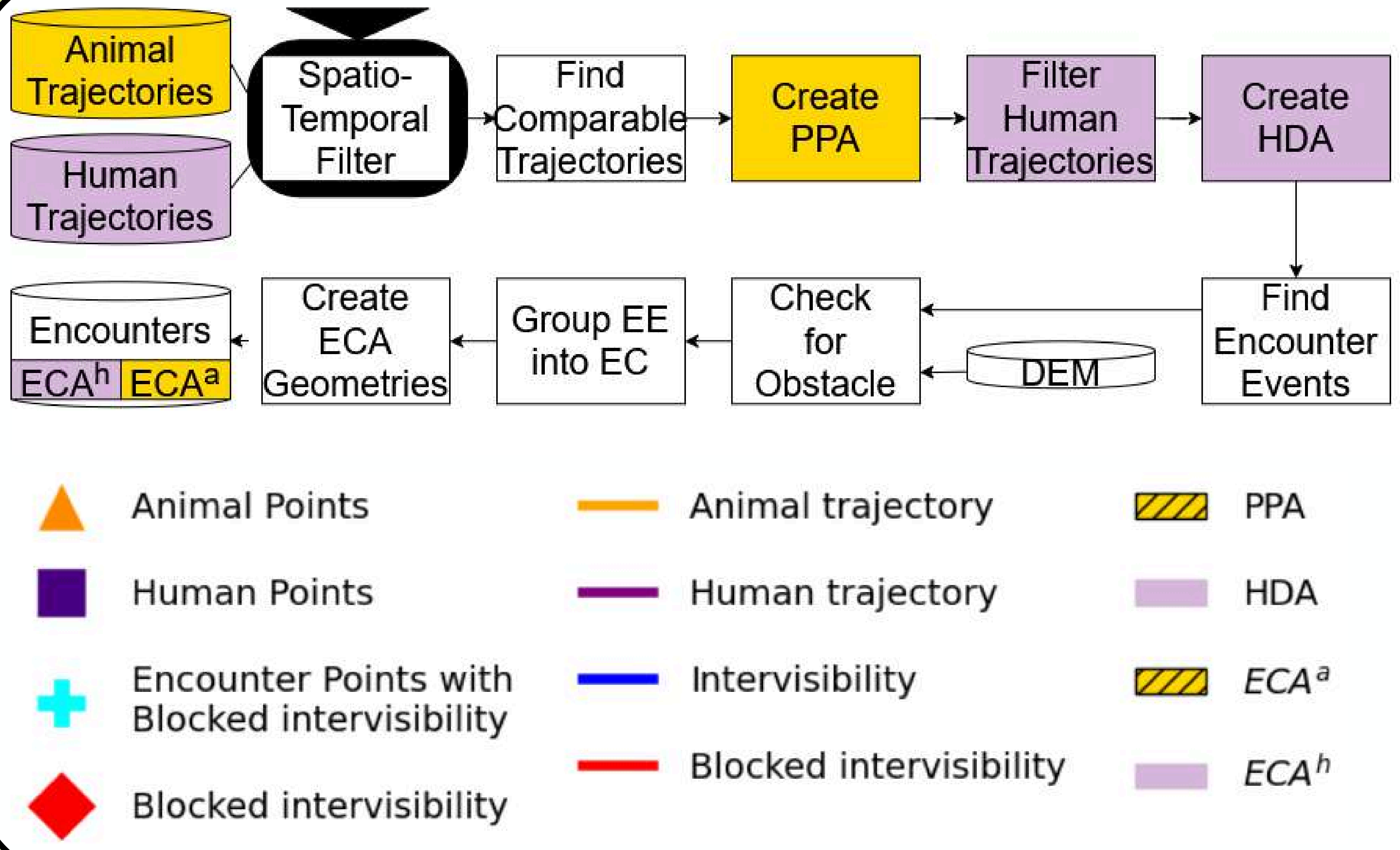
ECA^a **= Encounter Area Animal**

ECA^h **= Encounter Area Human**




Method

Encounter Detection Method



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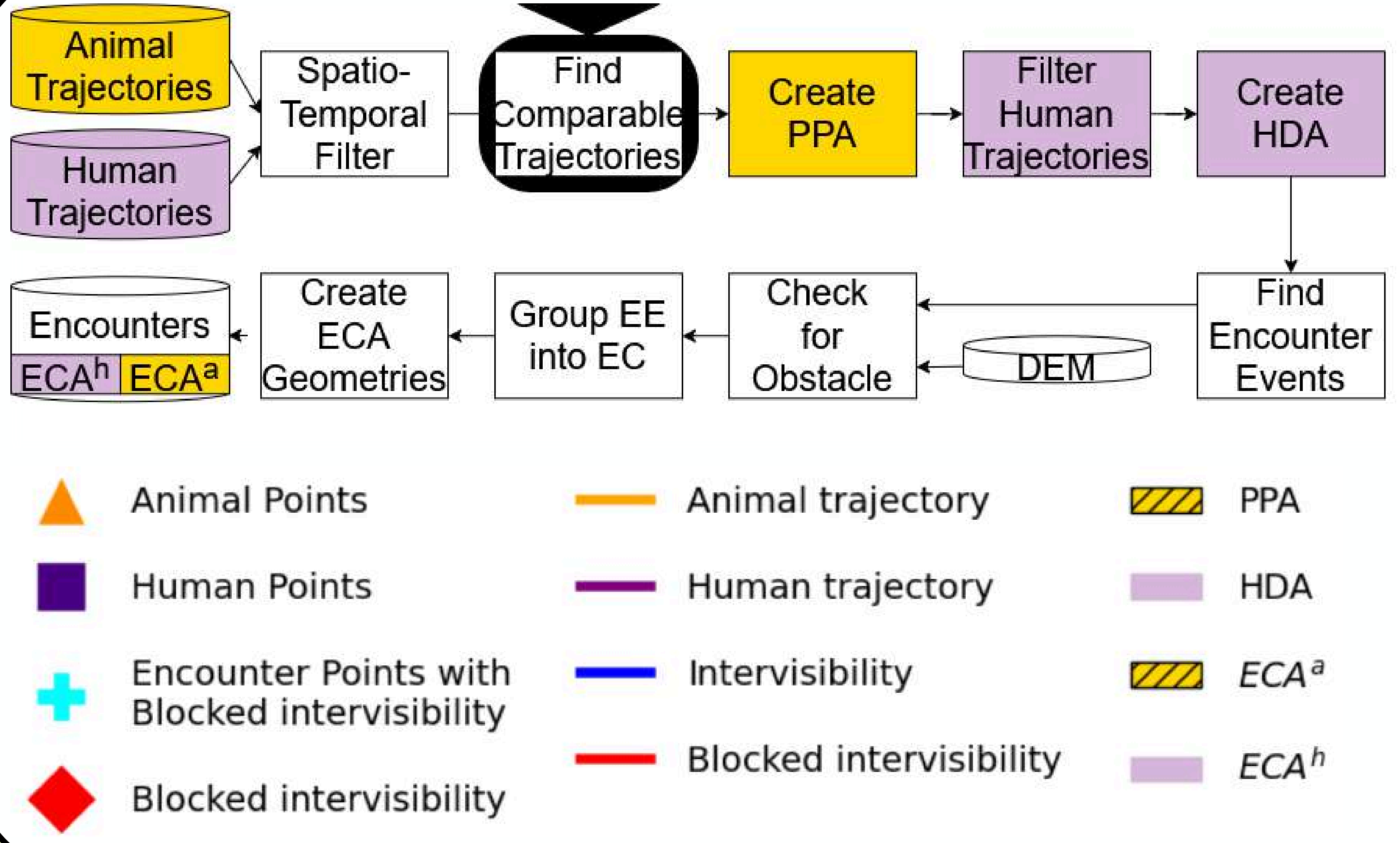

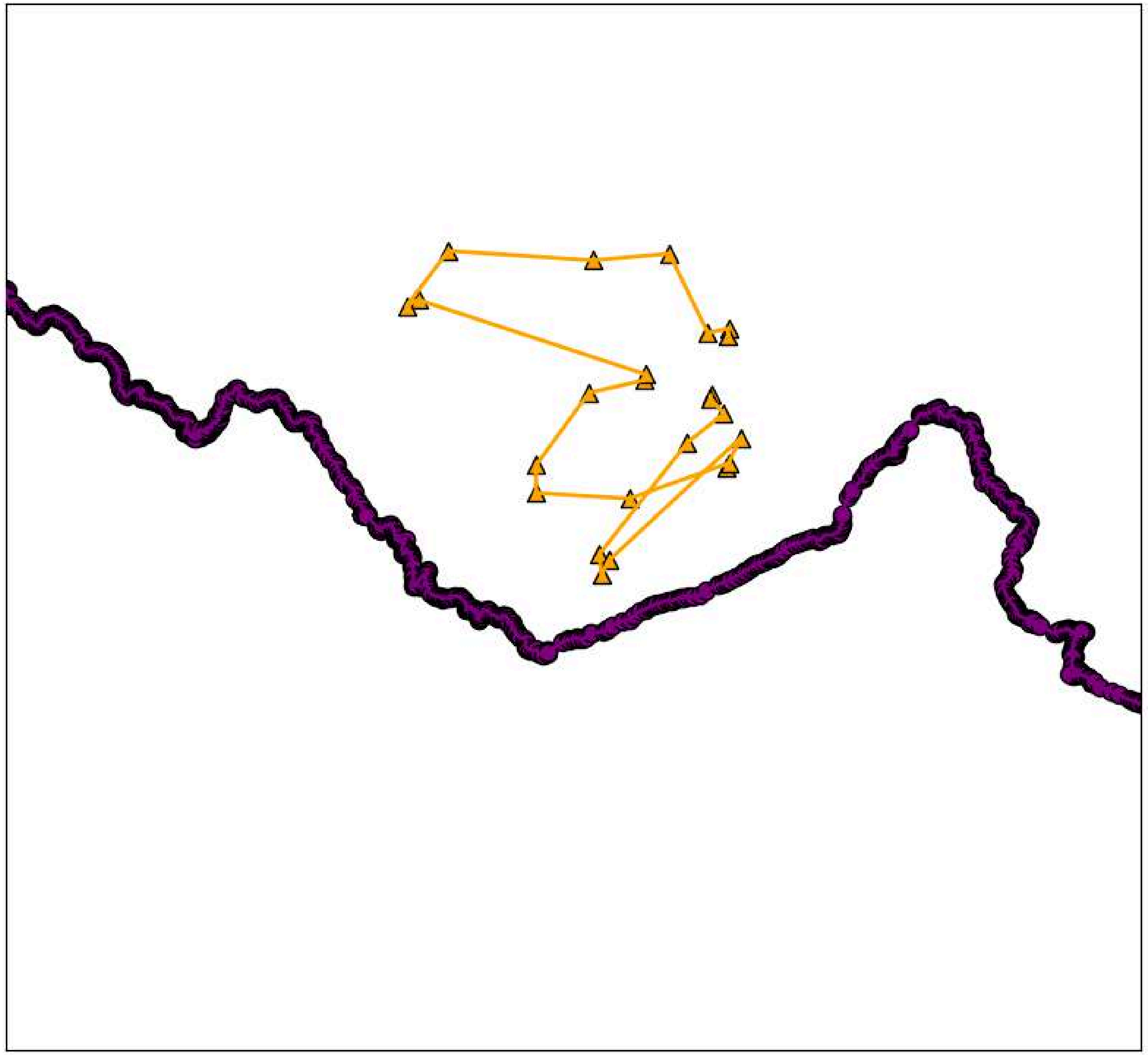

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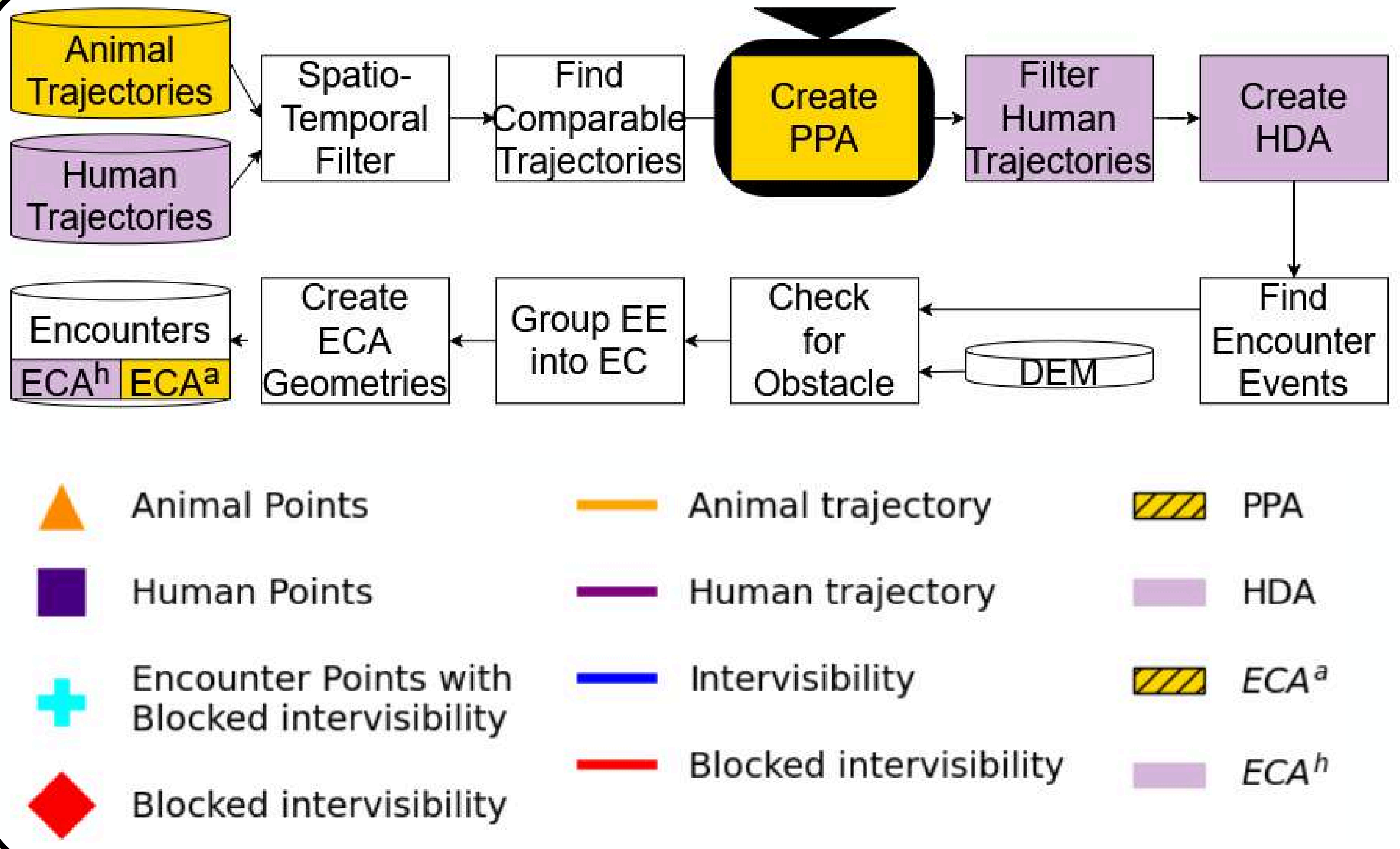

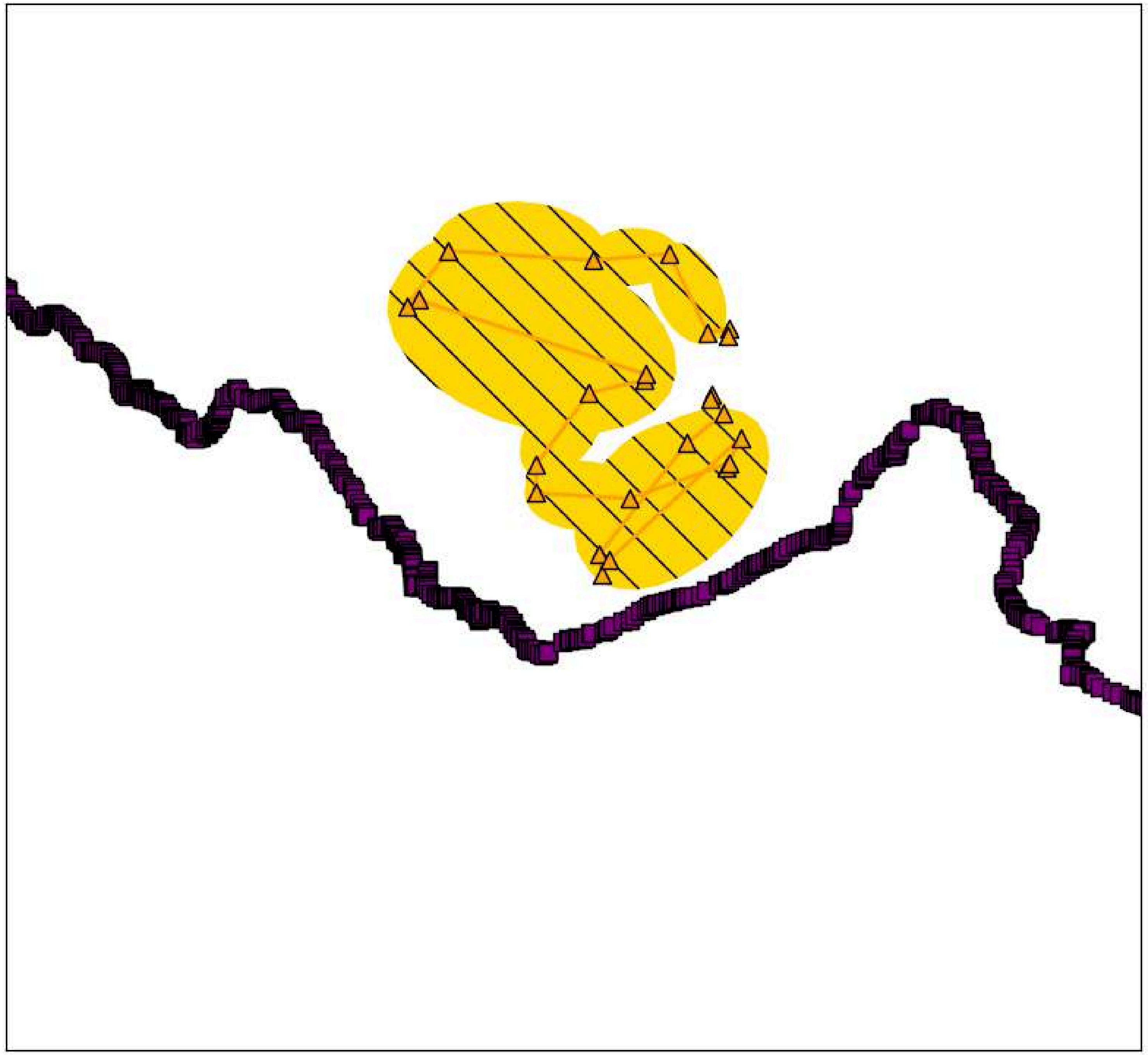

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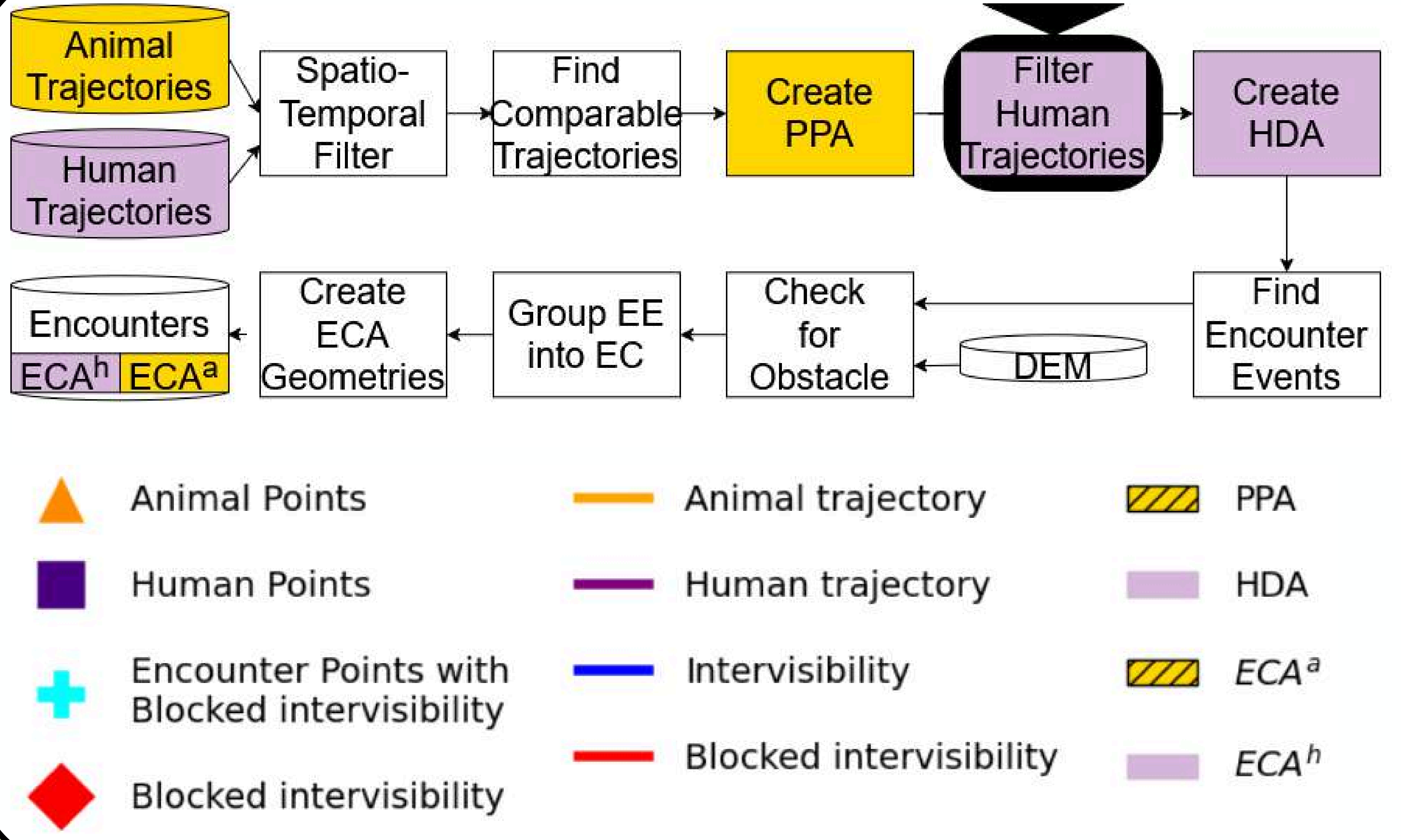

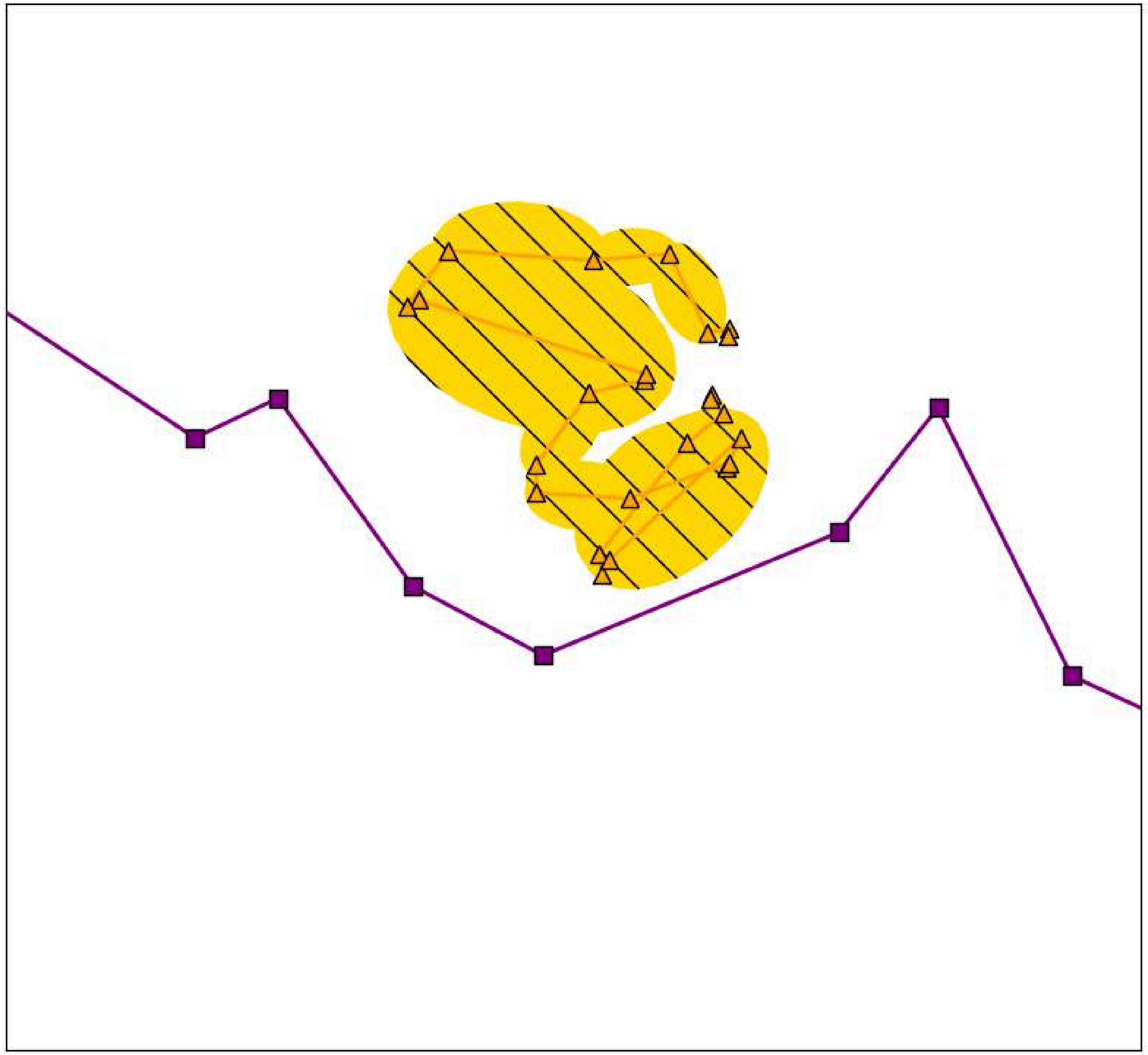

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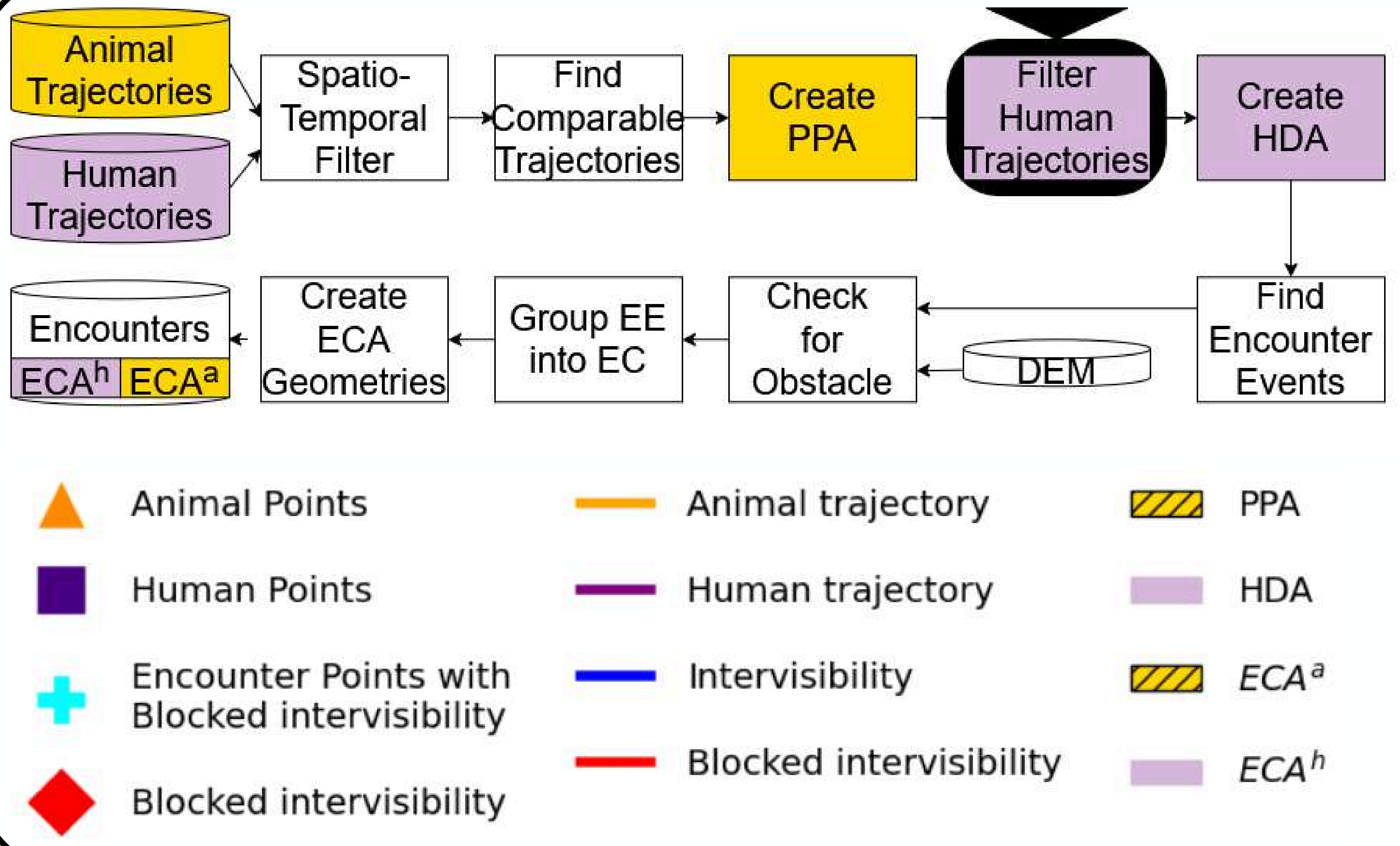

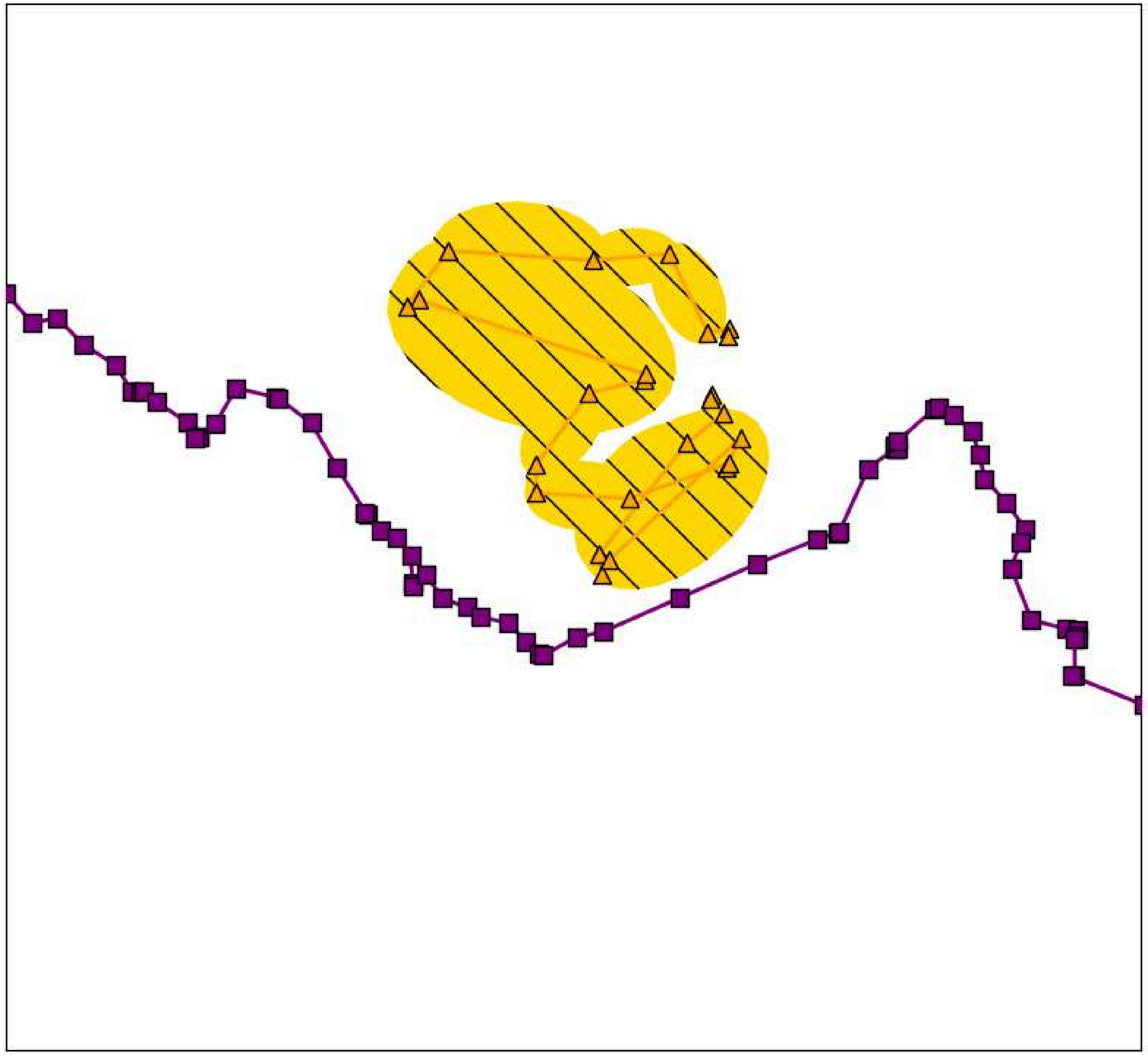

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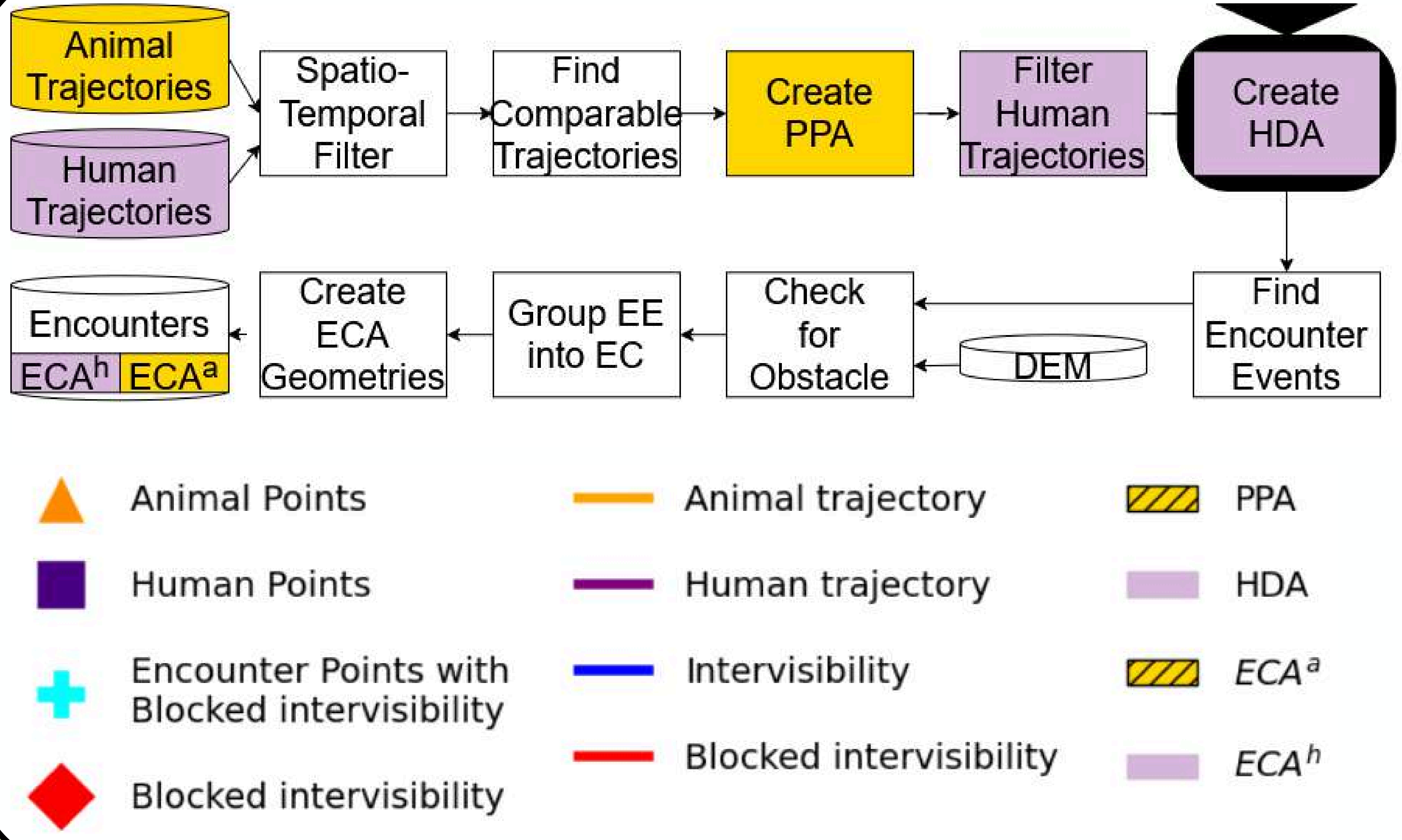

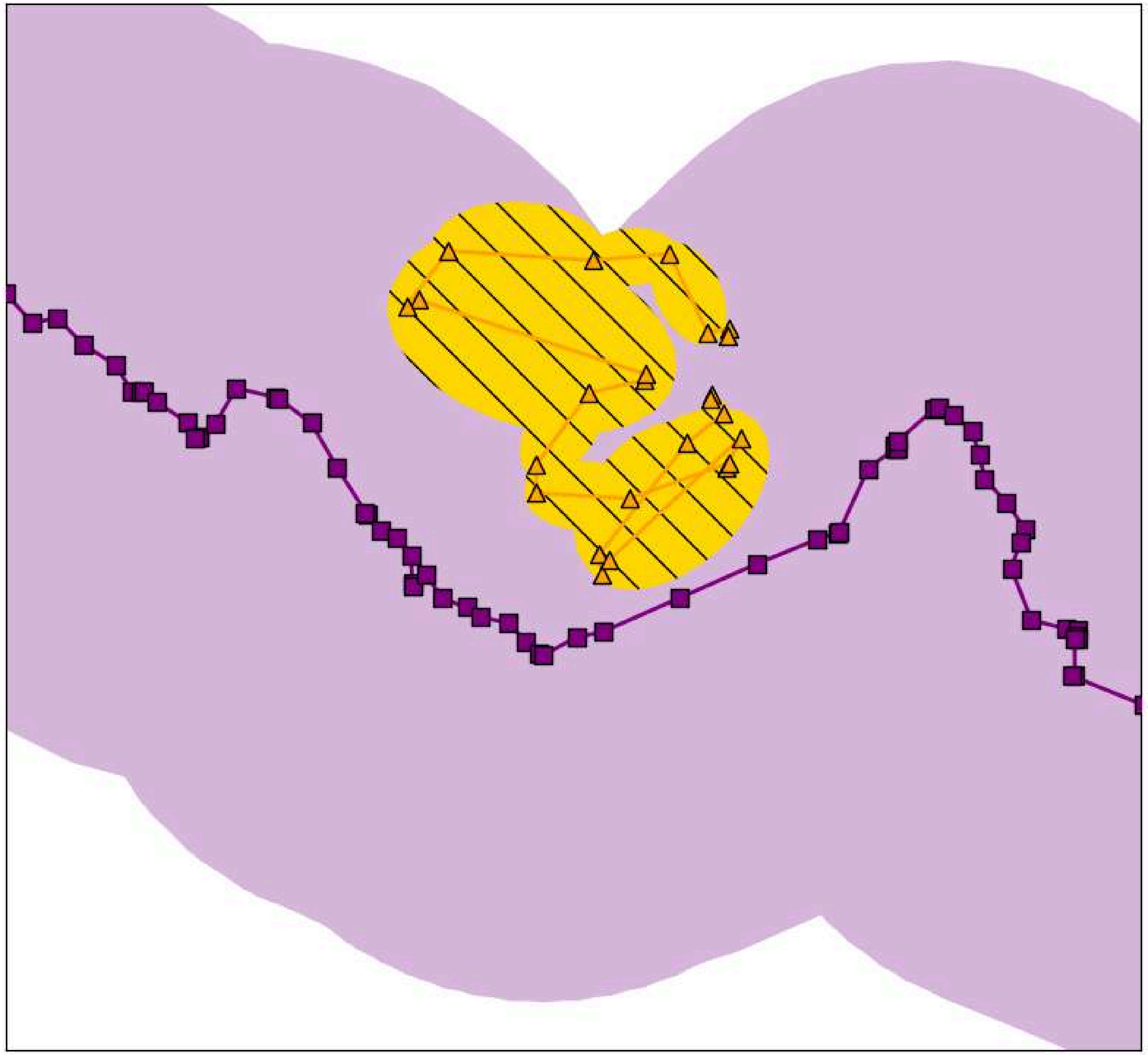

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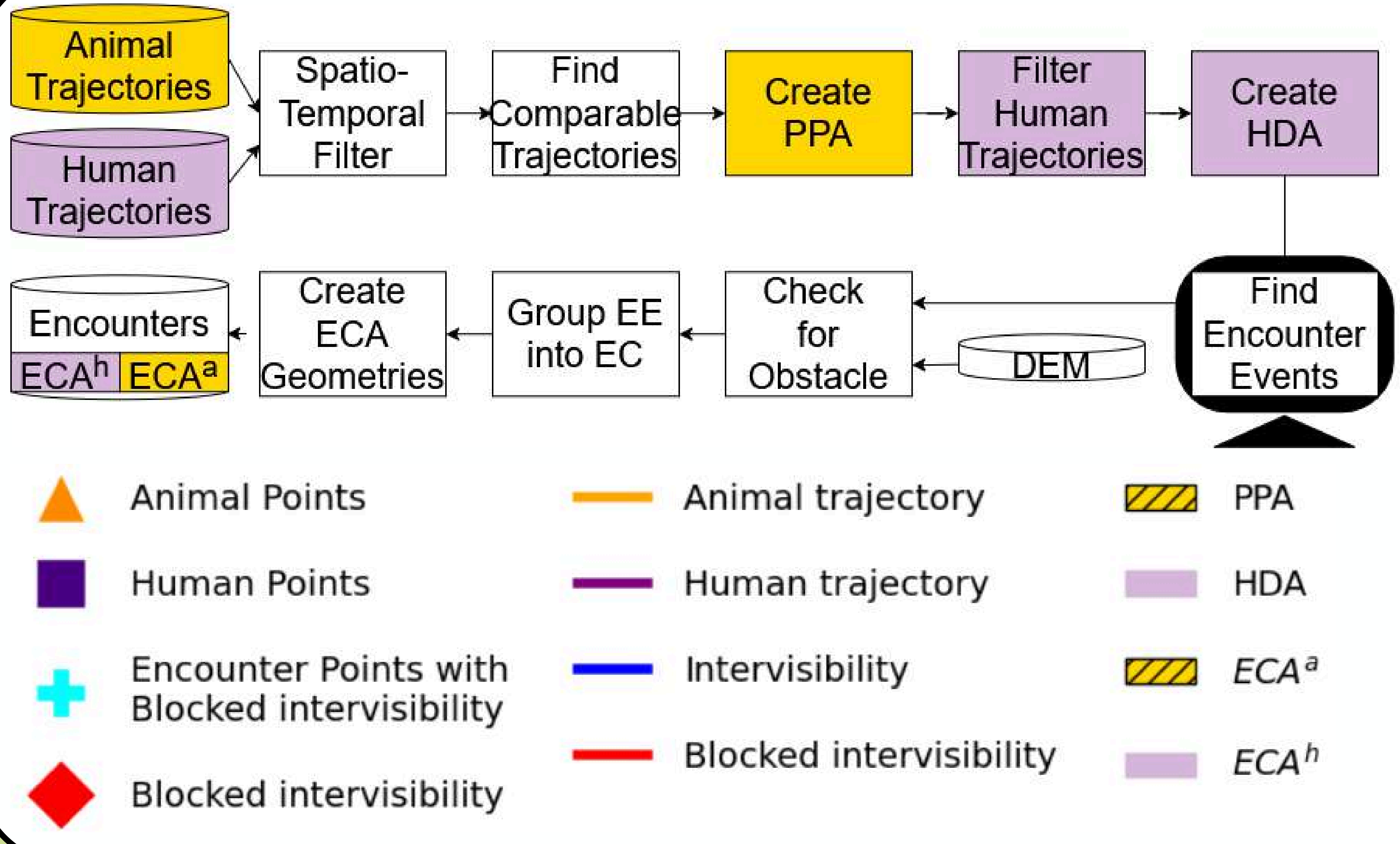

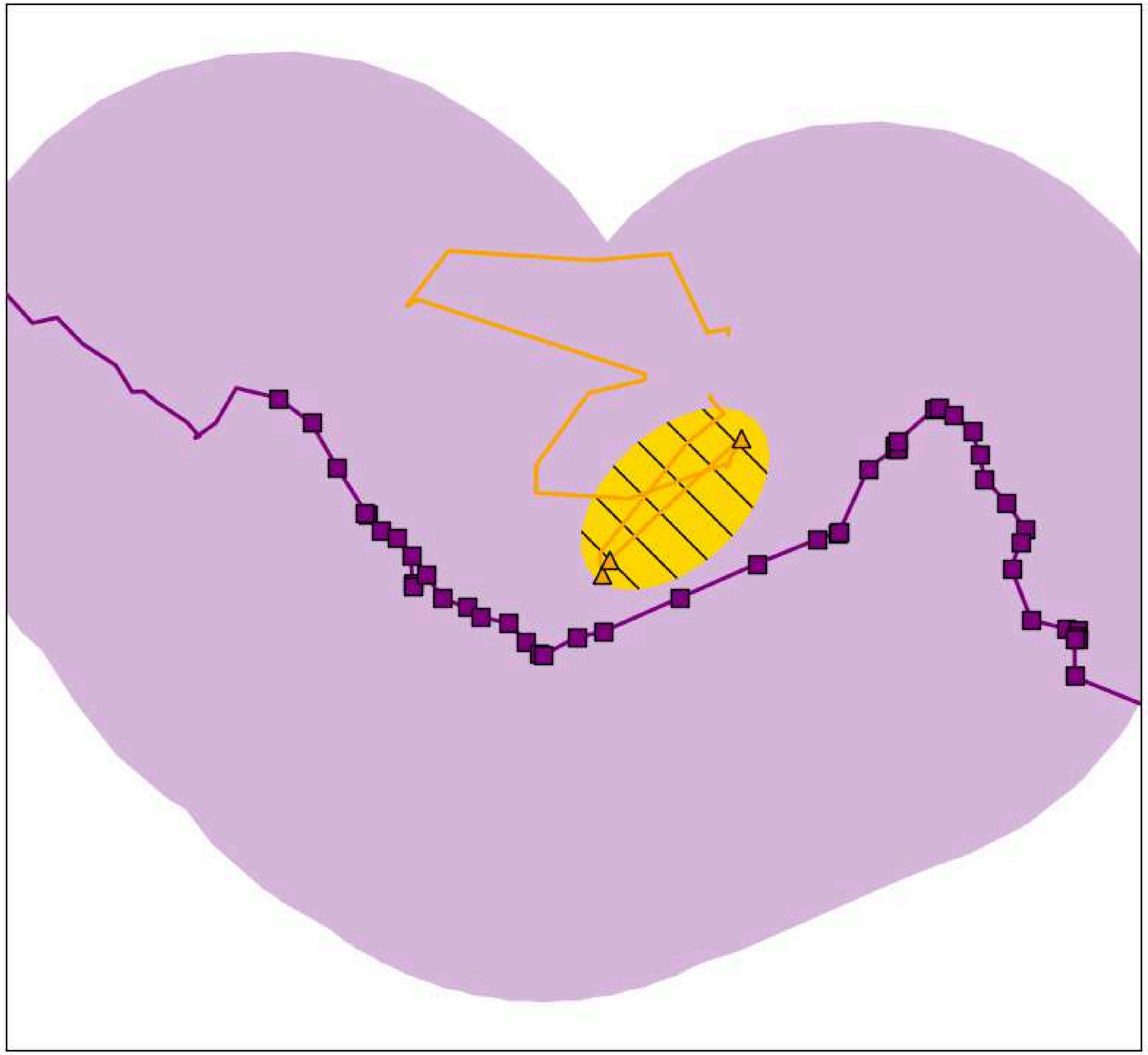

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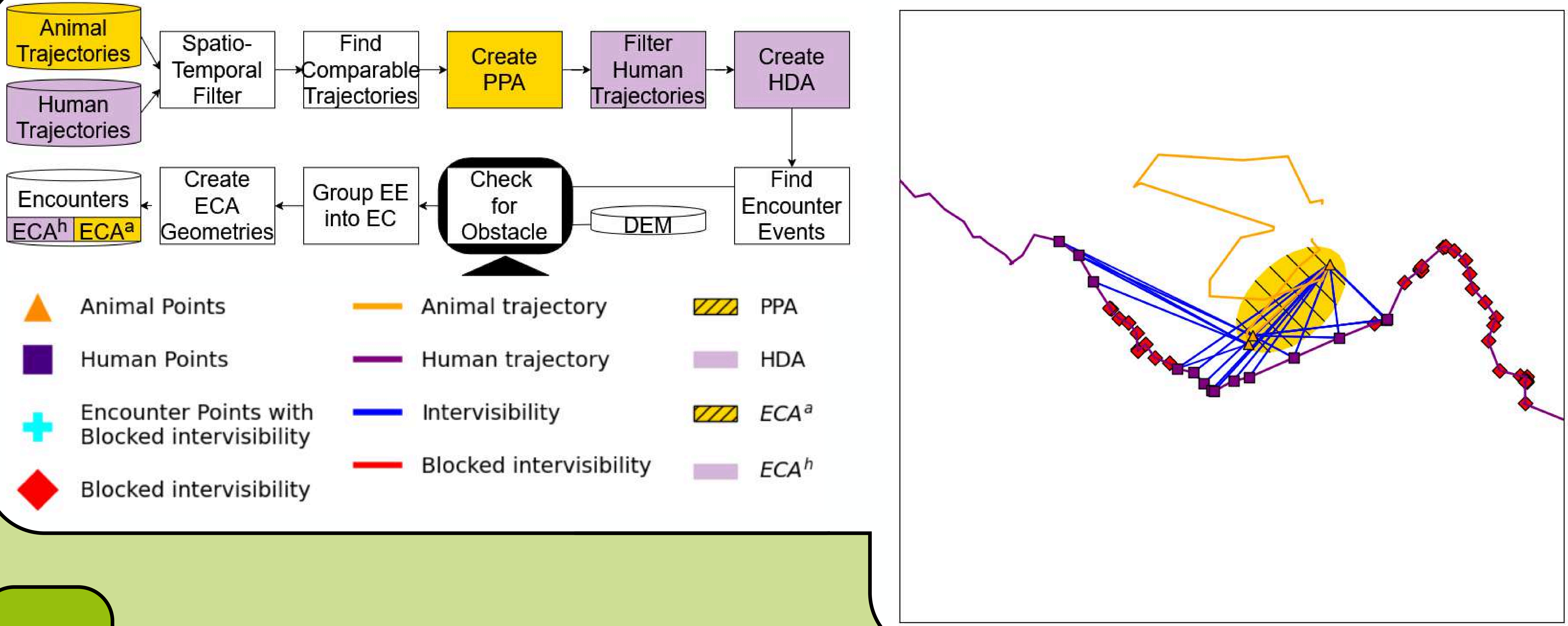

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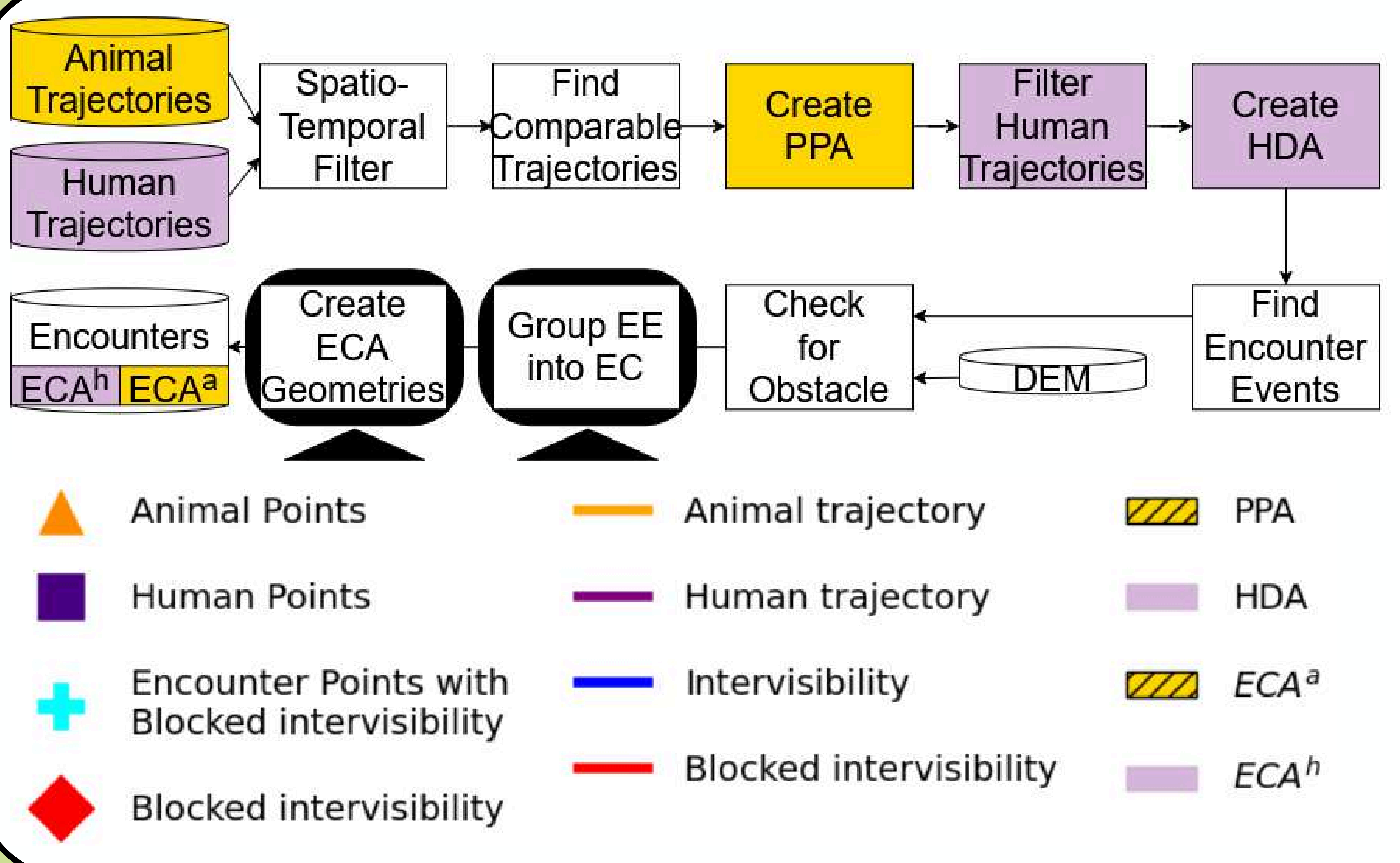
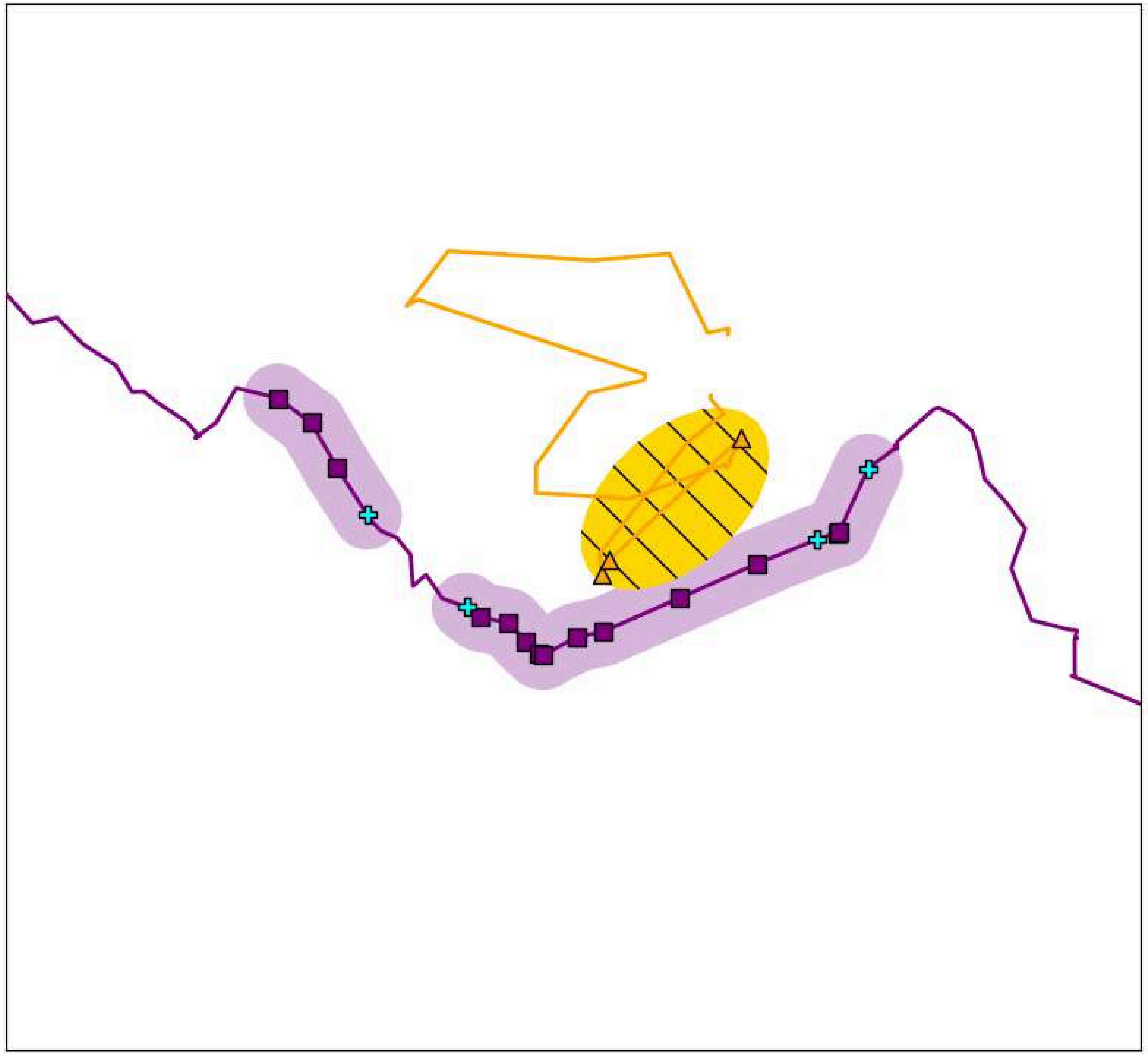


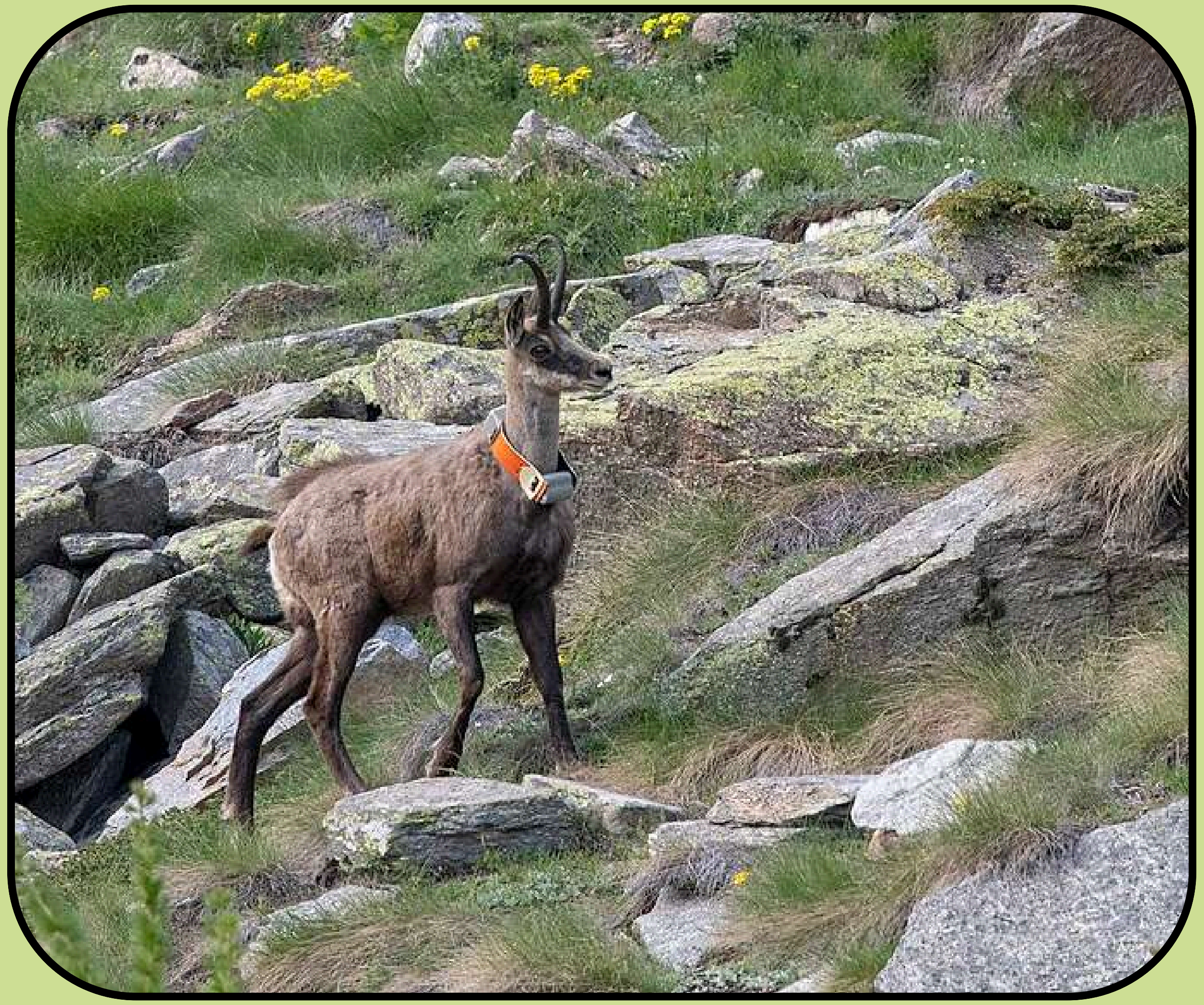


Experiment Setup

Study Area : National Game and Wildlife Reserve of Bauges Massif, French Alps

Data-Chamois

- 82,685 trajectories for 257 recorded animals
  - 218 females and 39 males
  - Each trajectory represents a single day
  - Only 19,173 with temporal granularity of at least 1 point/hour



Data-Human

- From multiple sources
- Better granularity
- Represented
  - Hikers
  - Runners
  - Skiers

Source	Number of trajectories	Temporal granularity (points/sec)
CampToCamp	10	1/60
GPSRando	6	1/13
Strava	2282	1/1
Visu	211	1/3
VTTour	44	1/5
Survey project	281	1/4

Parameters

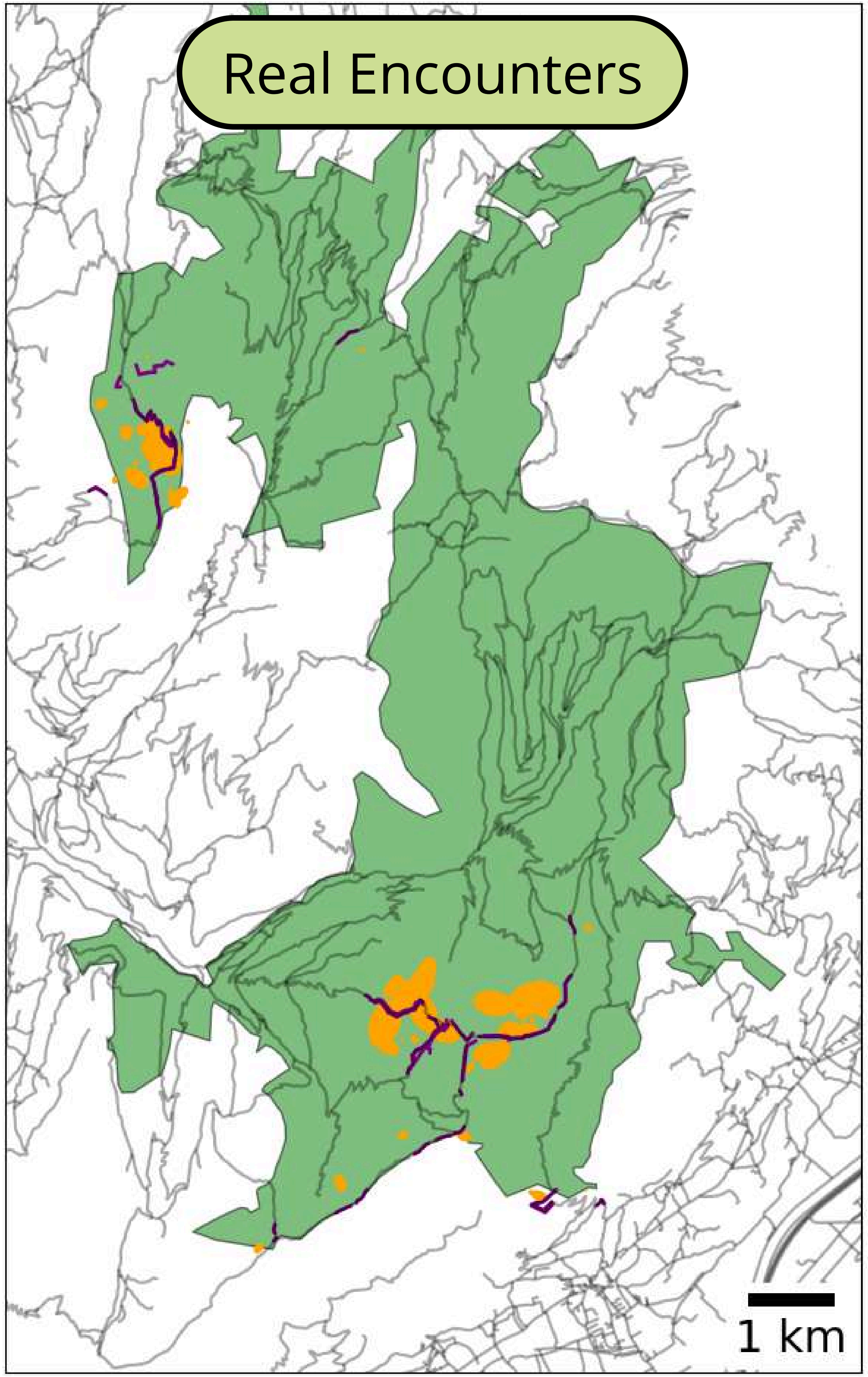
- Set from expert opinion or using sensitivity study
- *HDA_radius* set from (Hamr, 1988; Courbin et al., 2022)

Name	Step	Value
doy_shift	2 : Find Comp Traj	15 days
max_speed	3 : Create PPA	1.25*spd
d_gap^a	3 : Create PPA	500 m
min_dist	4 : Filter Human Traj	25 m
min_time	4 : Filter Human Traj	1 min
HDA_radius	5 : Create HDA Traj	250 m
d_gap^h	5 : Create HDA Traj	500 m
$height^h$	7 : Check for Obstacle	1.6 m
$height^a$	7 : Check for Obstacle	1 m
t_gap	8 : Group EE into EC	8 min
ECA^h_radius	9 : Create ECA geom	10 m


Results

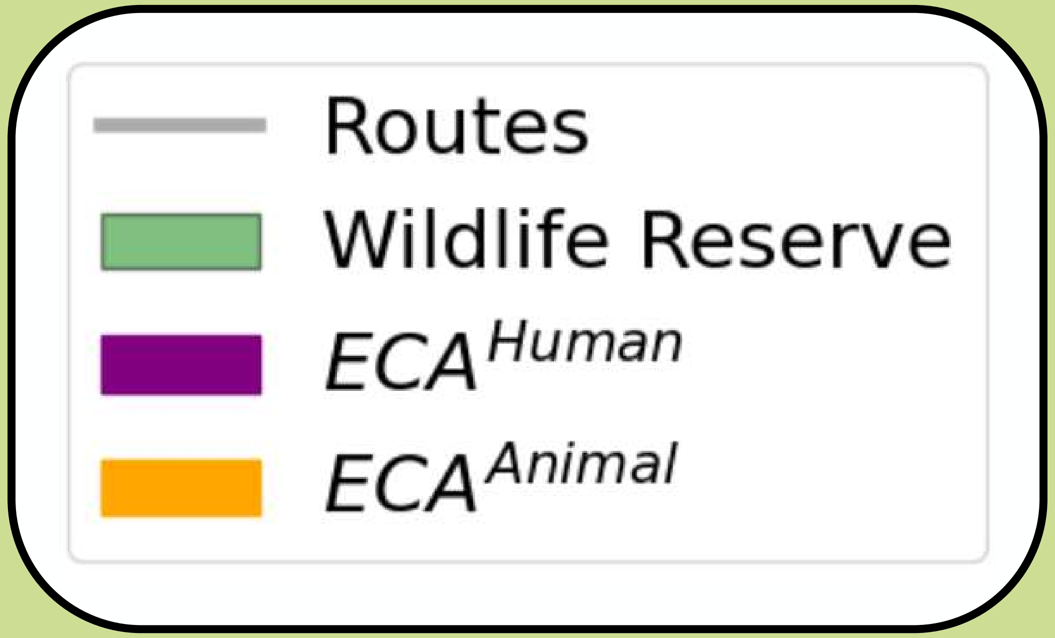
Results

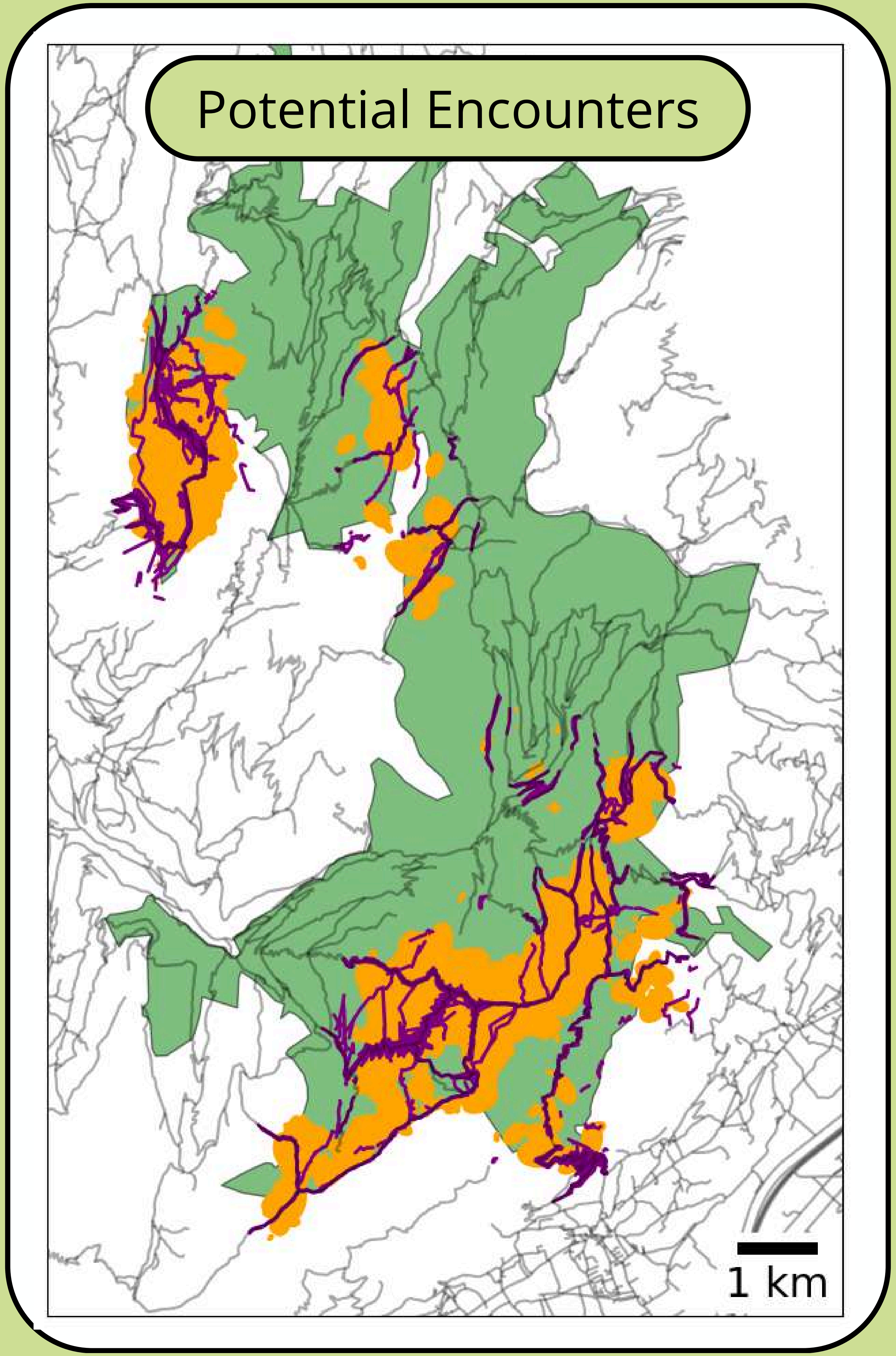
- Real encounters: 185

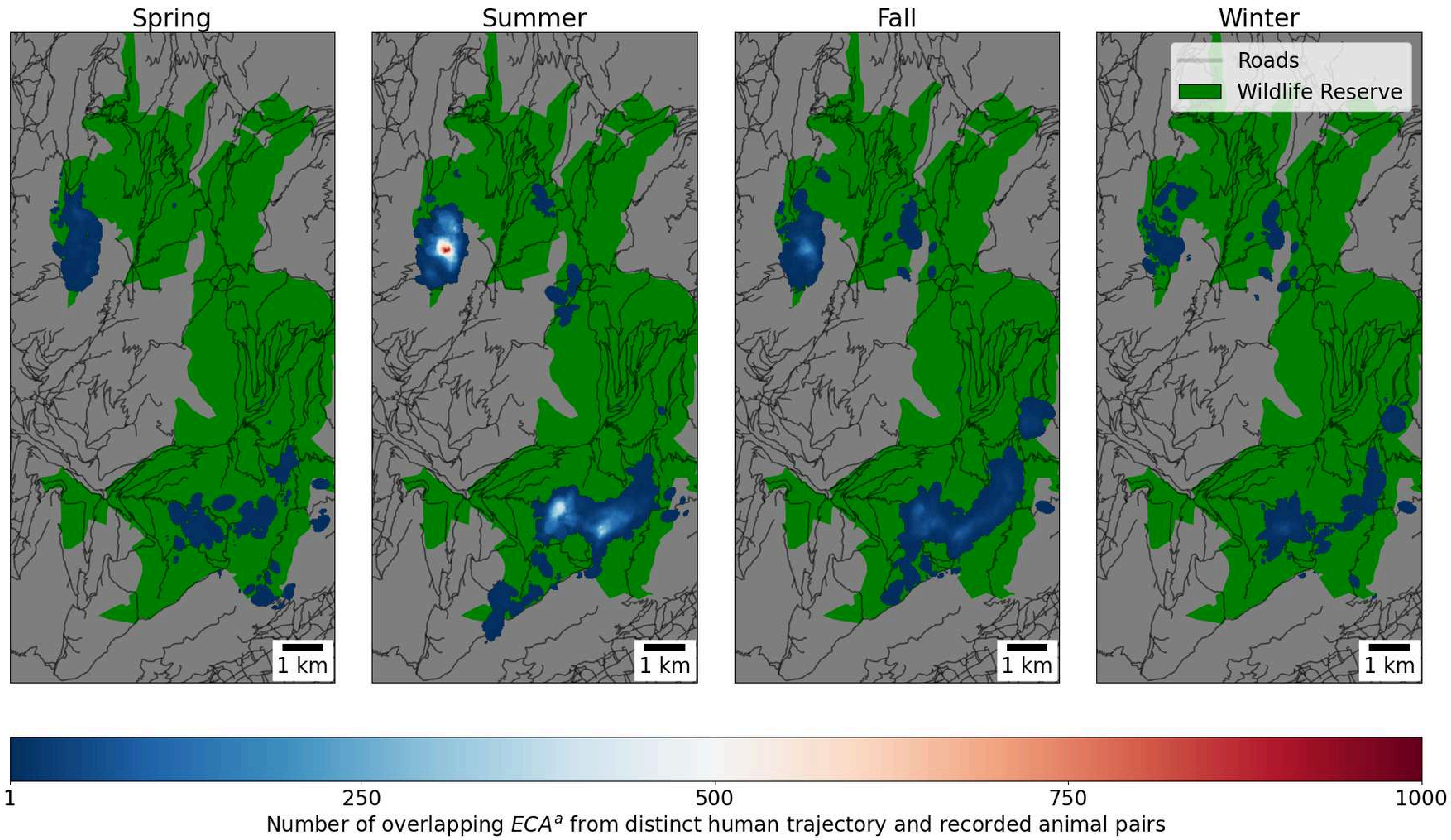


Results

- Real encounters: 185
- Potential encounters: 63,078



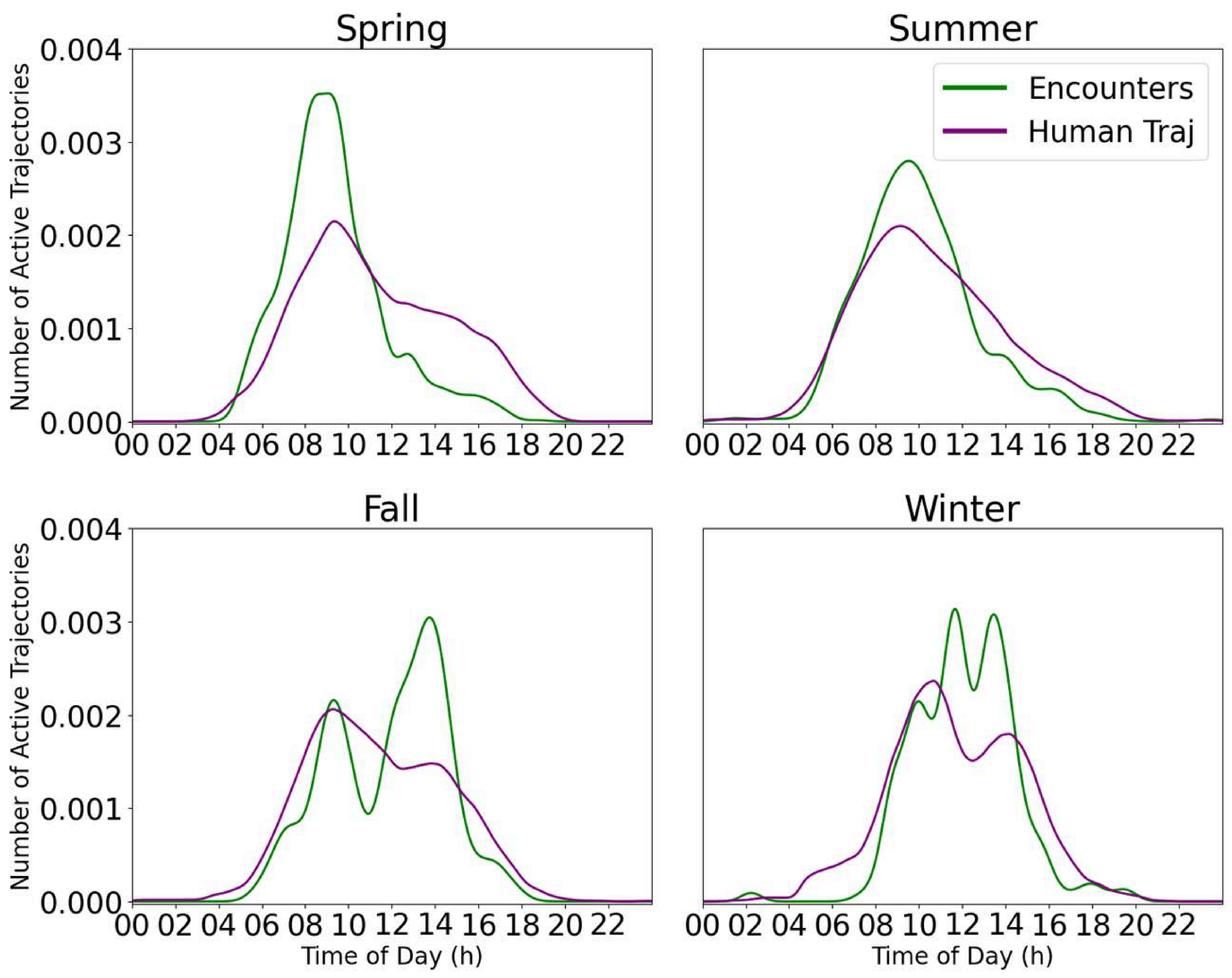




Spring
Summer
Fall
Winter
Roads
Wildlife Reserve
1 km
1 km
1 km
1 km
1
250
500
750
1000
Number of overlapping ECA^a from distinct human trajectory and recorded animal pairs

Results-Time of Day

- Y-axis: Kernel density estimation
  - Number of human trajectories
  - Number of encounters



Conclusion

Recap

- Presented an encounter detection method
  - Accounts for distance of affect
  - Incompleteness of data
  - Works with heterogeneous data quality
  - Can be generalized to other applications

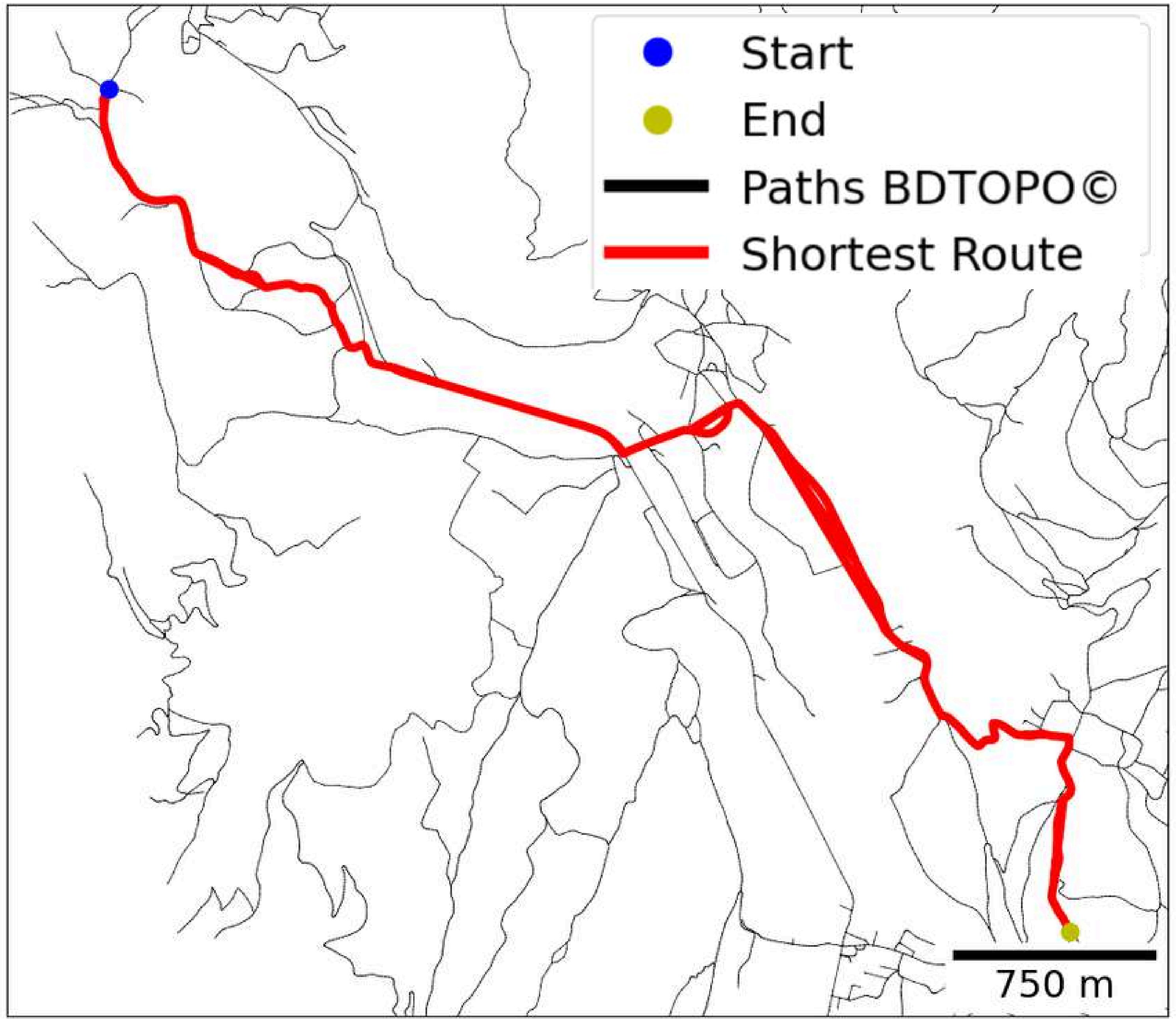
Generalization

- Red Deer
  - Decrease HDA_radius
  - Remove intervisibility constraint

- Wolf
  - Increase HDA_radius
  - Extend the HDA_radius in prevailing wind detection
  - Decrease doy_shift or only real encounters

Future works

- Expanded analysis of the animal behavior before and after encounters
- ‘Resilient Route Recommendation System’ with environmental awareness



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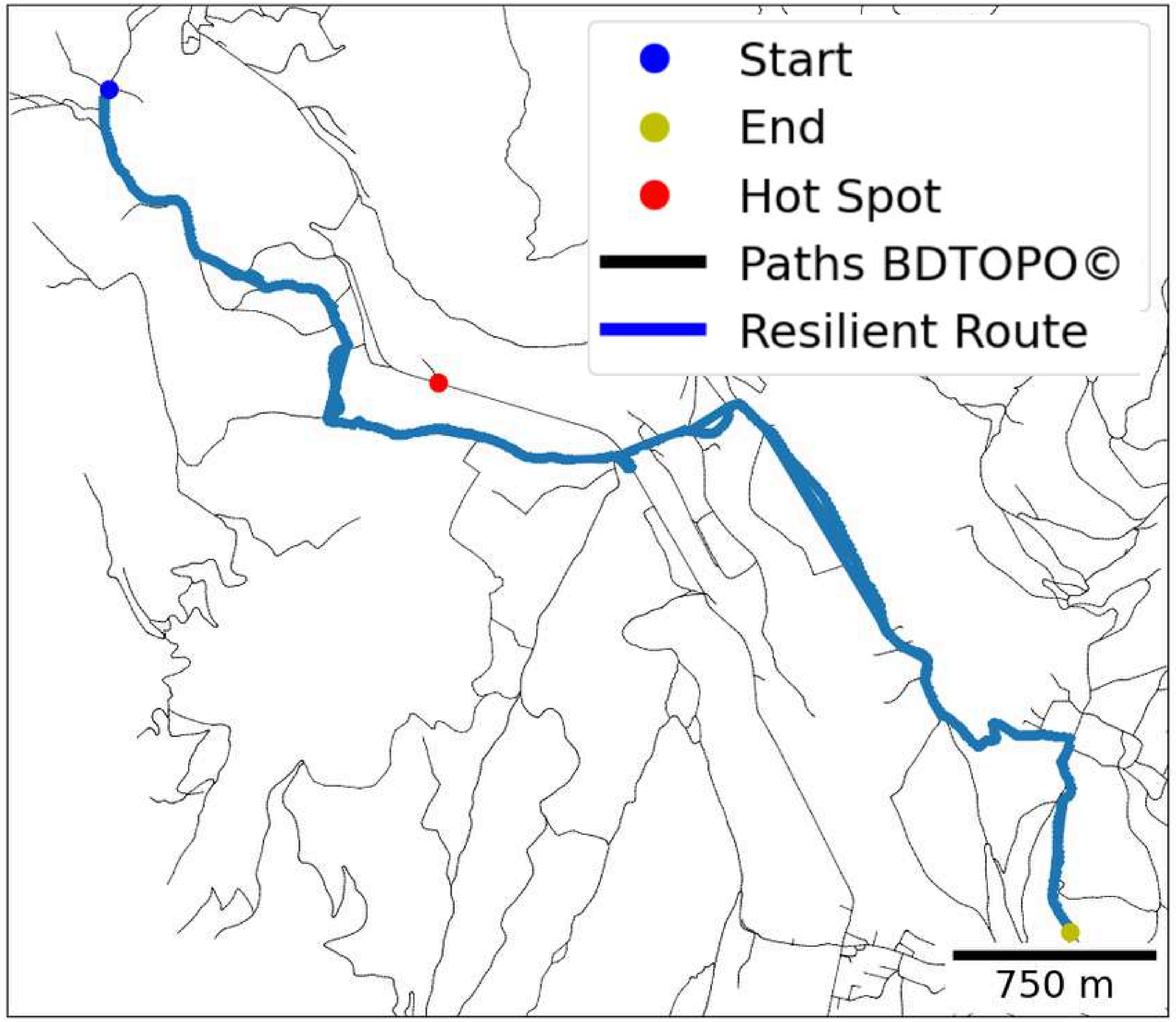

Thank you for your attention

Github link

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Images

3 13 *Francesca Lo Manto*, Creative Commons Attribution-Share Alike 4.0 - **Alpine chamois (Rupicapra rupicapra) with radio collar - Gran Paradiso National Park**
https://commons.wikimedia.org/wiki/File:Camoscio_geo_localizzatore.jpg

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https://fr.wikipedia.org/wiki/Chamois#/media/Fichier:Rupicapra.jpg

19 © *Giles Laurent*, gileslaurent.com, License CC BY-SA - **Wild alpine chamois family at Creux du van with snow during golden hour**
https://fr.wikipedia.org/wiki/Chamois#/media/Fichier:009_Wild_Alpine_Chamois_Family_Photo_by_Giles_Laurent.jpg

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https://en.wikipedia.org/wiki/Wolf#/media/File:Eurasian_wolf_2.jpg

20 *Lviatour*, **Cervus elaphus (Red deer)**
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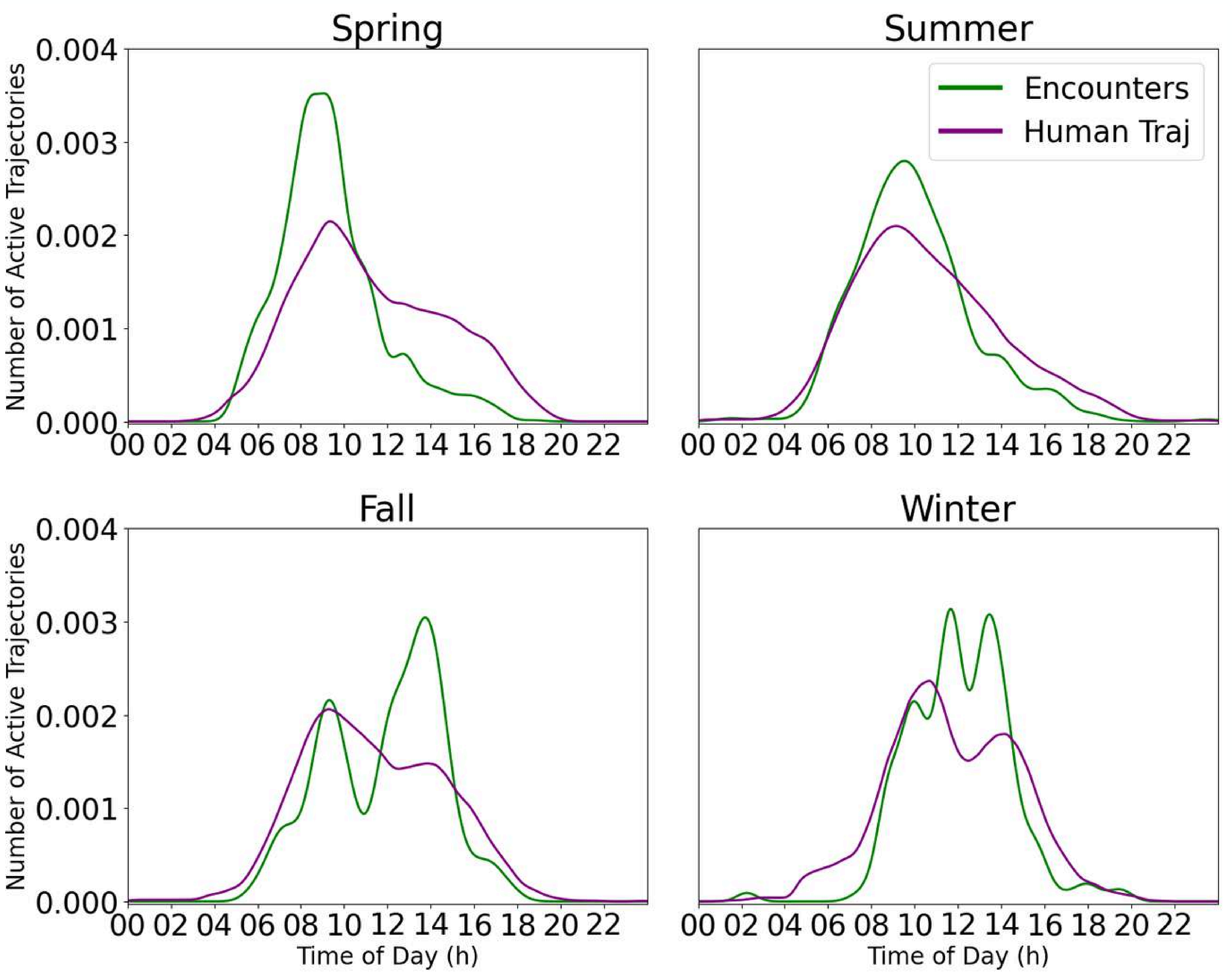
Wild baby chamois in the Aletsch Forest Nature Reserve
https://fr.wikipedia.org/wiki/Chamois#/media/Fichier:013_Wild_Baby_Chamois_Riederalp_Photo_by_Giles_Laurent.jpg

21 *Florian Pépellin*, Travail personnel
Vue panoramique, depuis la Pointe de la Galoppaz (1 681 mètres d'altitude), de la partie sud du massif des Bauges, à l'est de Chambéry, en Savoie.
https://fr.wikipedia.org/wiki/Massif_des_Bauges#/media/Fichier:Panoramique_Sud_des_Bauges_(2014).JPG

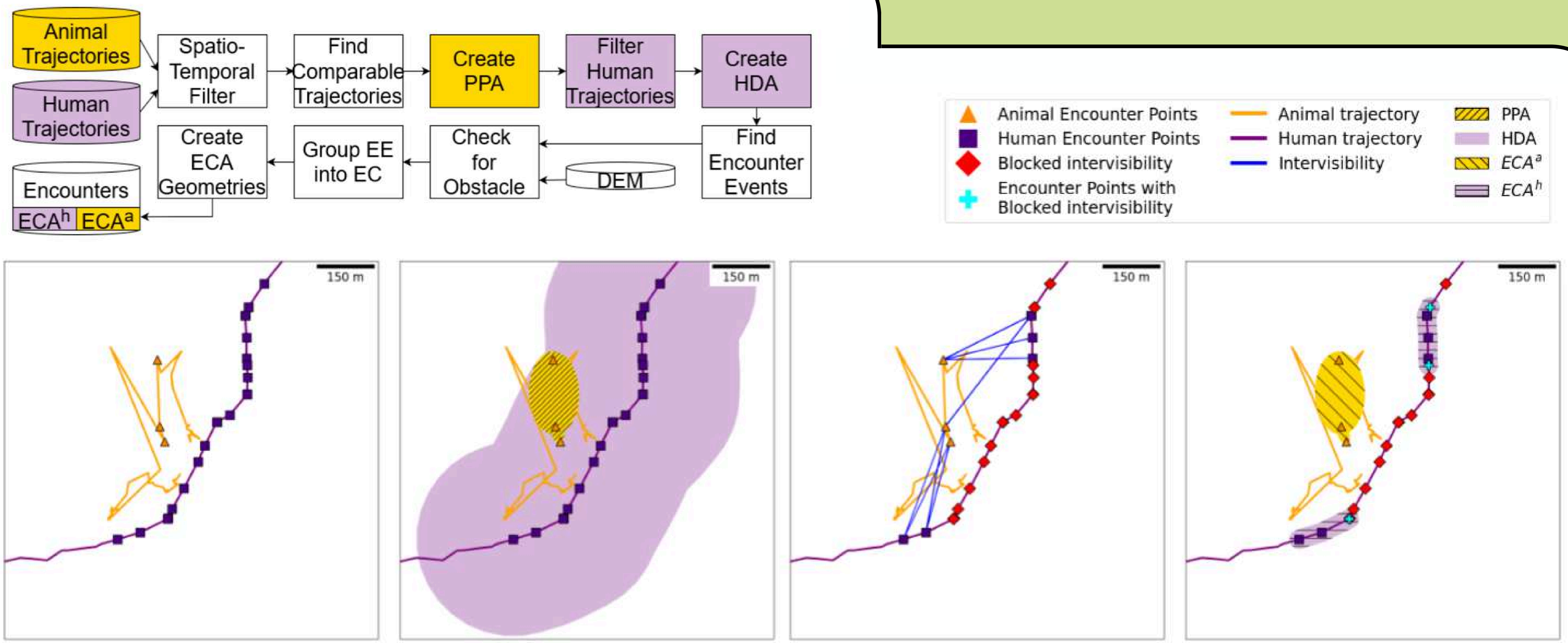
Concept	Acronym
Human point	$P_i^h = (p_i, t_i)$
Animal point	$P_j^a = (p_j, t_j)$
Point position	$P_k(p)$
Point timestamp	$P_k(t)$
Human disturbance area	$HDA_{i,i+1}$
Potential path area	$PPA_{j,j+1}$
Available area	AA_m
Encounter event	EE_k
Encounter event initial time	$EE(t_0)$
Encounter event final time	$EE(t_f)$
Day of year	doy
Obstacles preventing disturbance	Ω
Encounter	EC
Encounter duration	$EC(\Delta t)$
Encounter area^{animal}	ECA^a
Encounter area^{human}	ECA^h

Results-Time of Day

- Y-axis: Kernel density estimation
  - Count assigned to all bins the encounter's or trajectory's duration intersect respectively



Encounter Detection Method



(a) Steps 1-2 (b) Steps 3-6 (c) Step 7 (d) Steps 8-9

Settings

Metric	Default	HDA_radius = 500 m	Intervisibility Ignored
EE [count]	663,357	1,735,923	1,592,066
EC [count]	63,263	108,958	74,978
$EC(\Delta t)[min]$	12:02	17:45	21:21
ECA^h [m^2]	6,413	9,089	10,165
ECA^a [m^2]	12,079	11,403	13,017