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# Taking a Systematic Look at Movement: Developing a Taxonomy of Movement Patterns

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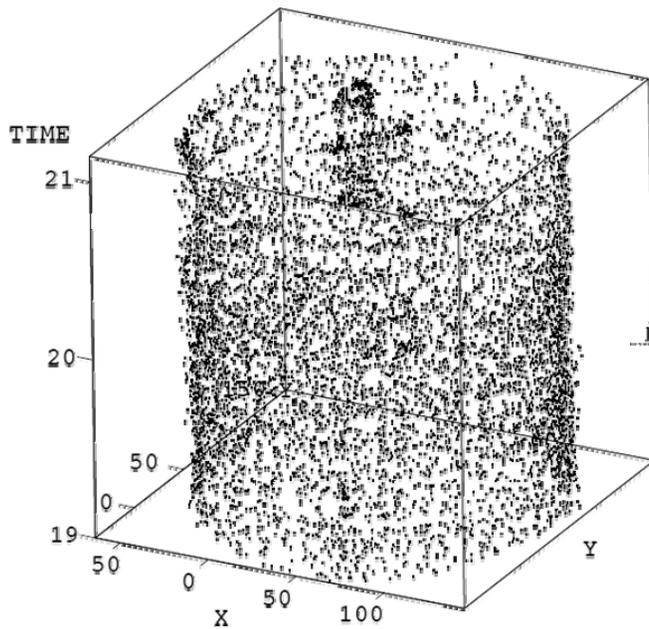
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# Motivation

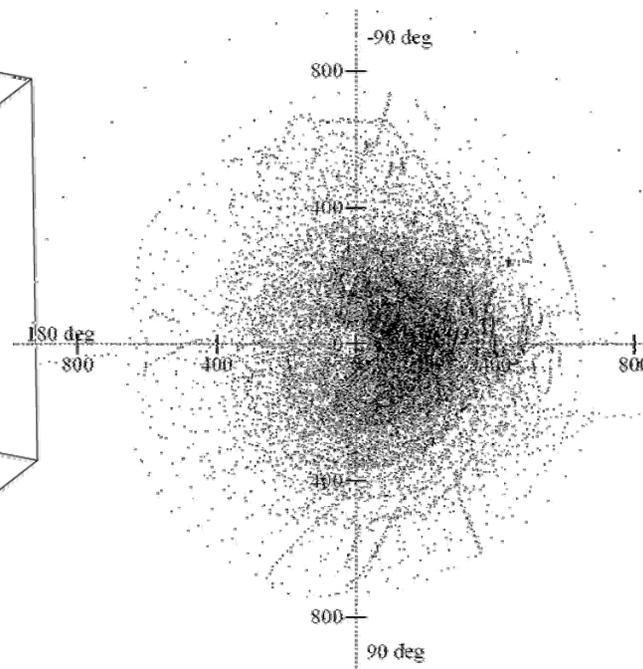
Design and develop of efficient data mining algorithms

- Generic and suitable for different kinds of MPO data.

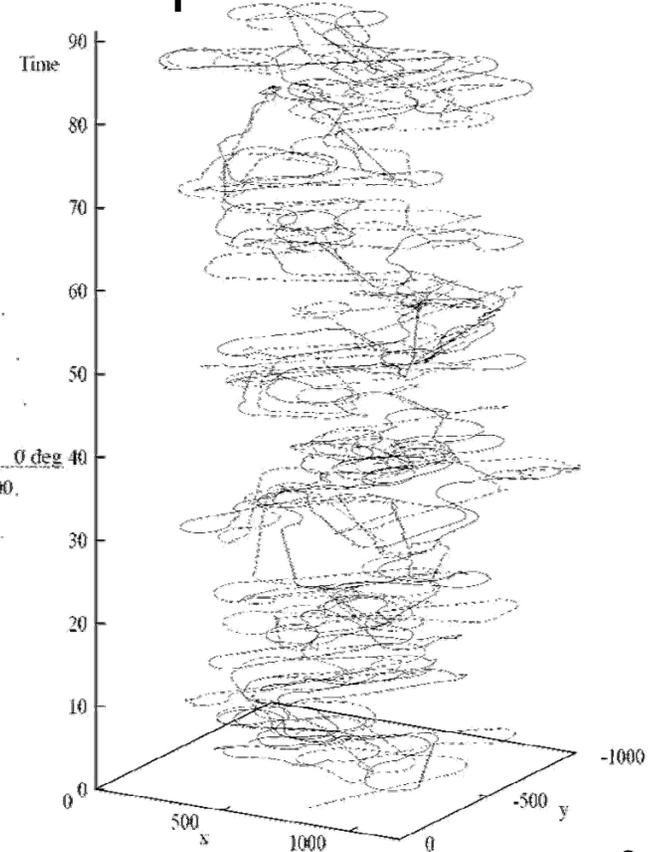
Definition of movement patterns is prerequisite to data mining and visual analytics



Imfeld (2000)



Blythe et al., (1999)





# Objectives

## Taking a Systematic Look at Movement

- **Conceptual foundations** for **movement behavior** of different moving objects
- A **comprehensive taxonomy**
- Accurate definitions of **movement patterns**

## Outcome:

**Interoperability** to gain the same understanding of the same terms.



# Conceptual Foundations

## Movement variables

Movement variables	Basic variables	Derived variables
Spatial (x,y)	Position (x,y)	Spatial distribution
	Distance $f(x,y)$	Change of direction (path curvature)
	Direction $f(x,y)$	
Temporal (t)	Instance (t)	Duration $f(interval)$
	Interval $f(t)$	Temporal distribution
		Change of duration
Spatio-temporal (x, y,t)	Speed $f(x,y,t)$	Acceleration $f(speed)$
	Velocity $f(x,y,t)$	

## Number of moving objects involved

- **Individual**
- **Group** with functional relationship
- **Cohort** with statistical relationship



# Conceptual Foundations (2)



## Path type (depending on the granularity)

- **Continuous** path (e.g. trajectory of elk migration)
- **Discontinuous** path (e.g. stop-and-go movement of butterflies)

## Influencing factors

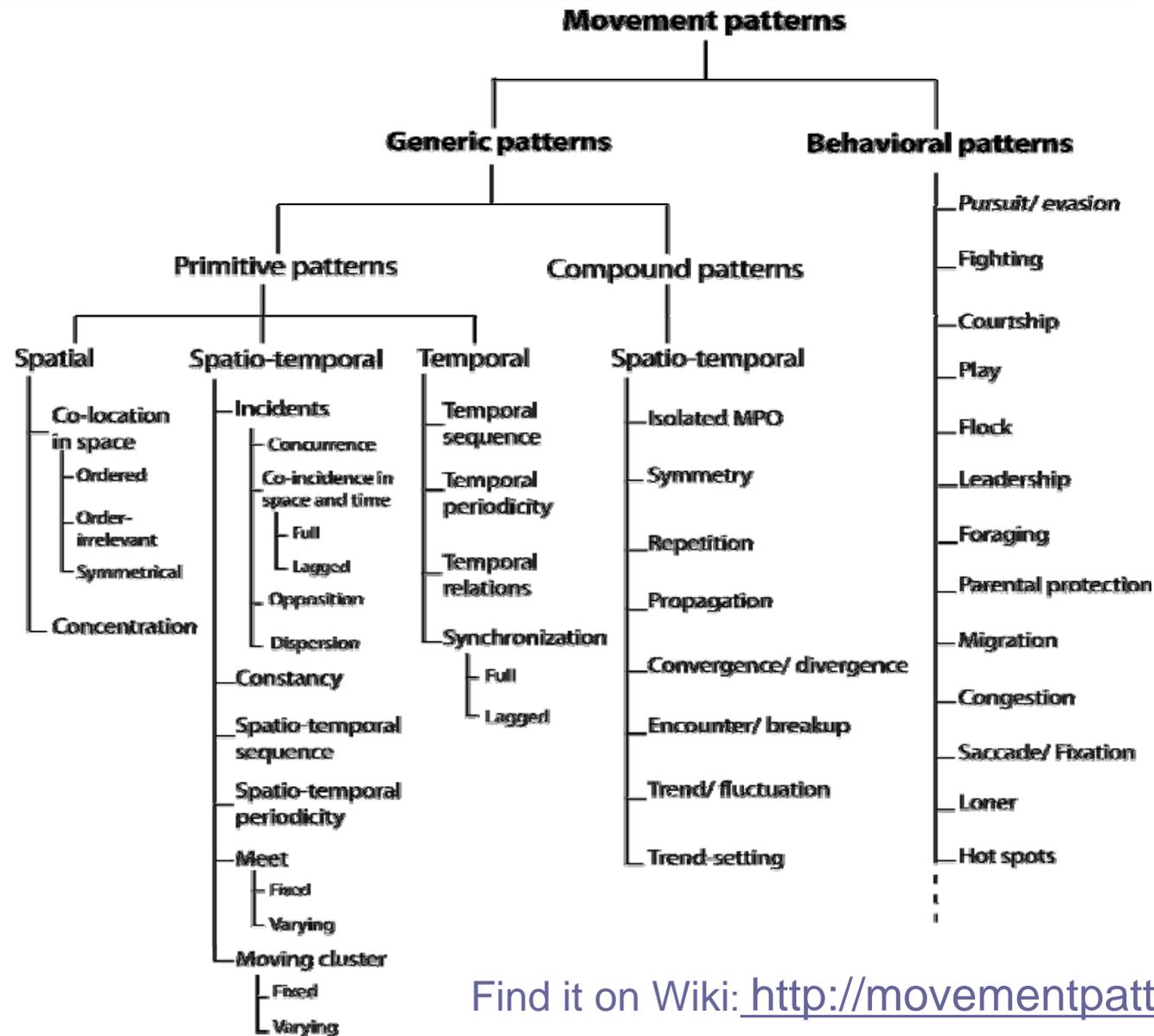
- Intrinsic properties of the MO (speed, acceleration etc.)
- Spatial constraints (network, barriers etc.)
- Environment (vegetation, image etc.)
- Influence of other agents (competition, attraction etc.)

## Scale/ granularity

- **Spatial** scale (very local to global scale)
- **Temporal** scale (very short-term to long-term behavior)



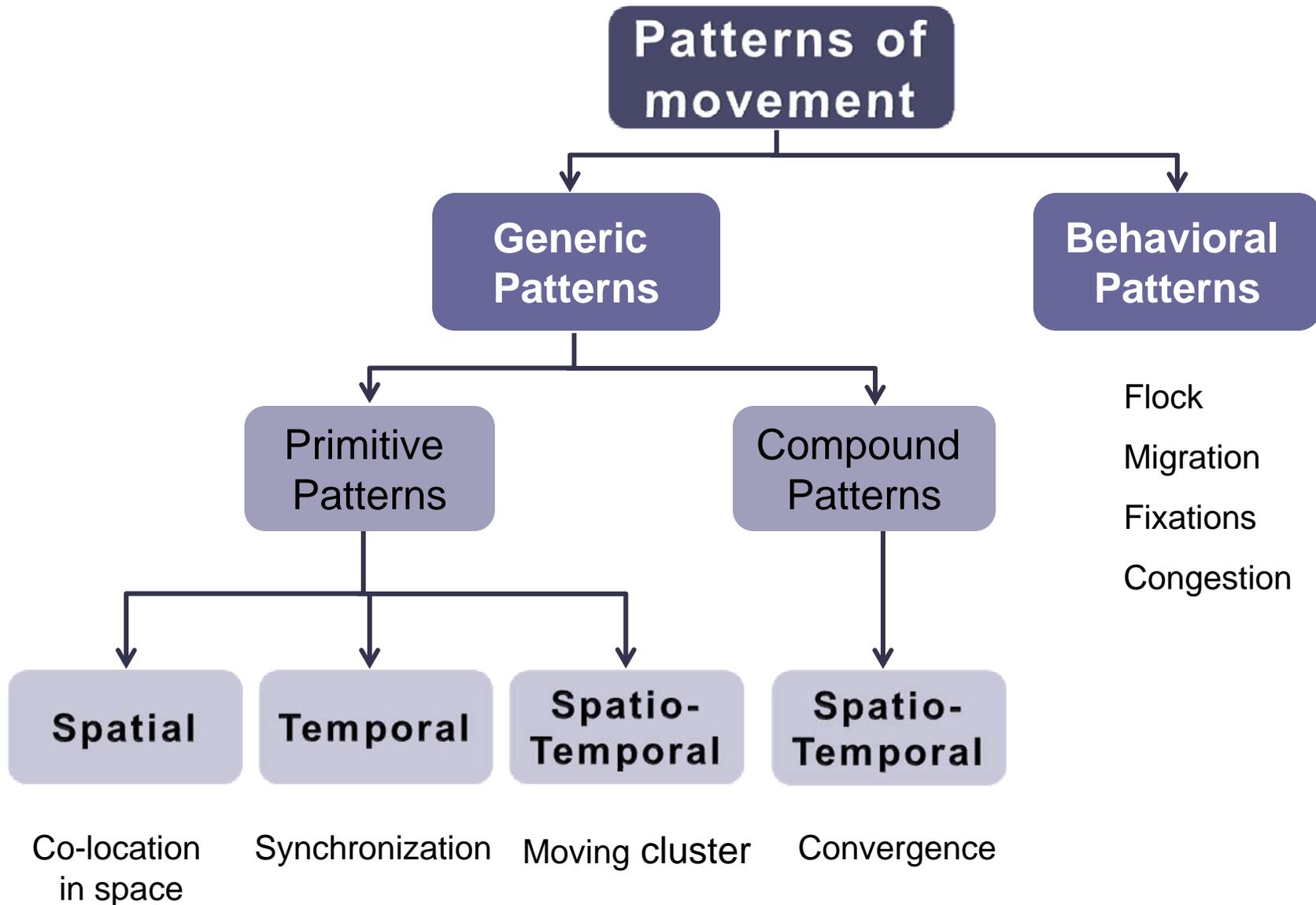
# Taxonomy of movement patterns



Find it on Wiki: <http://movementpatterns.pbwiki.com> 6

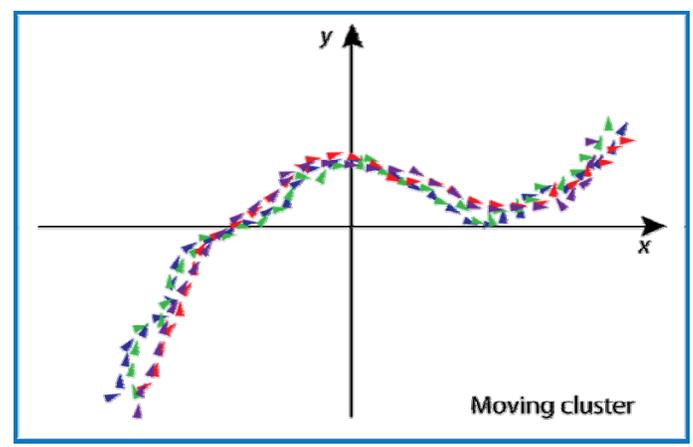


# Taxonomy of movement patterns

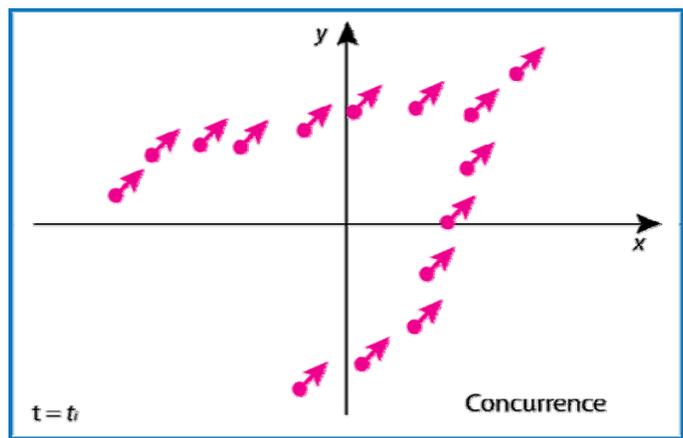


# Examples

## Generic Pattern

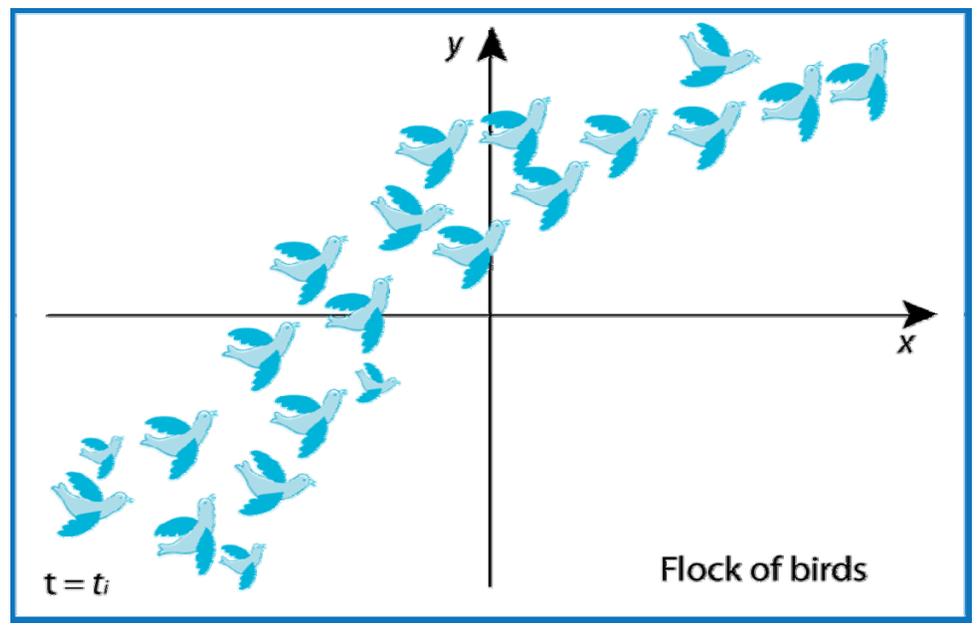


Moving Cluster



Concurrence

## Behavioral Pattern



Flock of birds

More examples on Wiki: <http://movementpatterns.pbwiki.com>

# Utilizing the taxonomy- Eye vs. human movement



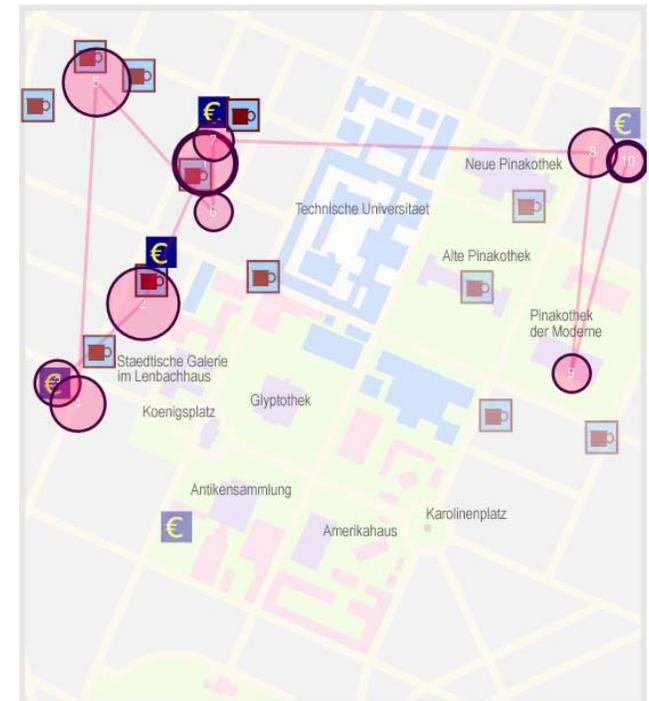
*“To what extent can we use **eye-movement** data as a **proxy** of other kinds of moving point data?”*

## Differences in movement behavior (examples):

- Different speed values, speed variation
- Rapid direction changes

## Movement pattern

- Similarities and differences
- Overlaid eye movement data from all subject
- A group of people taking part a guided tour
- Eye and human movement can be made comparable by stretching and compressing the spatial and temporal scales.



Reichenbacher (2007)

## Conclusion:

There are some commonalities between eye and human whole-body movements on the level of **generic movement patterns**.



# A call for collaboration

<http://movementpatterns.pbwiki.com>

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## Patterns of Movement

last edited by Somayeh Dodge 3 days, 20 hours ago Page history

### Patterns of Movement

In order to study the movement behavior of dynamic objects, it is important to take a closer look at movement itself. In other words, it is necessary to know what exactly the variables are that define movement, what constraints and external factors affect movement and most importantly to understand what types of movement patterns can be composed from these primitives of movement. Generally, movement patterns include any recognizable spatial and temporal regularity or any interesting relationship in a set of movement data, whereas the proper definition (i.e. the instantiation) of "pattern interestingness" depends on the application domain.

```

graph TD
    MP[Movement patterns] --> GP[Generic patterns]
    MP --> BP[Behavioral patterns]
    GP --> PP[Primitive patterns]
    GP --> CP[Compound patterns]
    PP --> S[Spatial]
    PP --> ST1[Spatio-temporal]
    CP --> T[Temporal]
    CP --> ST2[Spatio-temporal]
    S --> CLS[Co-location in space]
    CLS --> O[Ordered]
    CLS --> OI[Order-irrelevant]
    CLS --> SY[Symmetrical]
    ST1 --> I[Incidents]
    I --> C[Concurrence]
    I --> CIT[Co-incidence in space and time]
    CIT --> F[Full]
    CIT --> L[Lagged]
    CIT --> OPO[Opposition]
    T --> TS[Temporal sequence]
    T --> TP[Temporal periodicity]
    T --> TR[Temporal relations]
    ST2 --> IMPO[Isolated MPO]
    ST2 --> SYM[Symmetry]
    ST2 --> REP[Repetition]
    ST2 --> PRONA[Pronaation]
    BP --> PE[Pursuit/ evasion]
    BP --> FIGHT[Fighting]
    BP --> COURT[Courtship]
    BP --> PLAY[Play]
    BP --> FLOCK[Flock]
    BP --> LEAD[Leadership]
    BP --> FORAG[Foraging]
    BP --> PARENT[Parental protection]

```

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**Thanks for your attention!**



# Questions



- Why do you think it is necessary to have a comprehensive taxonomy and common definition of movement patterns?
- How do you expect the taxonomy to help algorithm developers in data mining and visual analytics?
- How do you think can the proposed taxonomy be extended to encompass future movement pattern data mining research?
- Who is willing to collaborate on the further development and consolidation of the proposed definition through the wiki?