SPATIOTEMPORAL SEMANTICS AND MOVING OBJECTS RESEARCH

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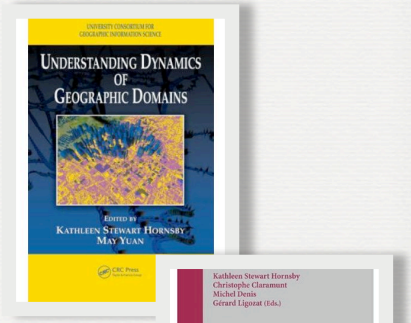
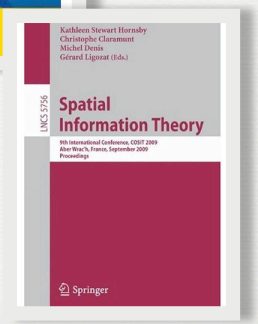
WHO I AM…

- **GIScience faculty** in Department of Geography, The **University of Iowa**
- Interested in **spatiotemporal modeling, moving objects** research, **geospatial semantics, ontologies** for **GIS**





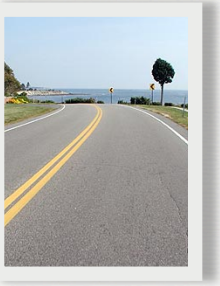
THE REAL WORLD…

- Interconnected…
- Continuous
- Dynamic

CONTINUANTS *VS* OCCURRENTS

- Continuant entities endure through some extended interval of time

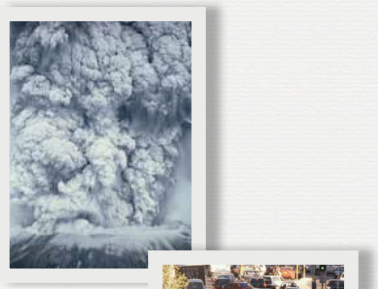
  Houses, roads, cities

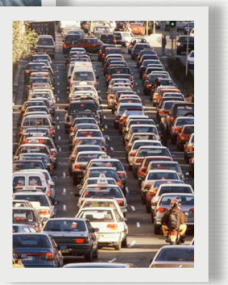


CONTINUANTS *VS* OCCURRENTS

- Occurrent entities happen and then are gone

  Traffic jams
  Volcanic eruptions
  Landslides, avalanches

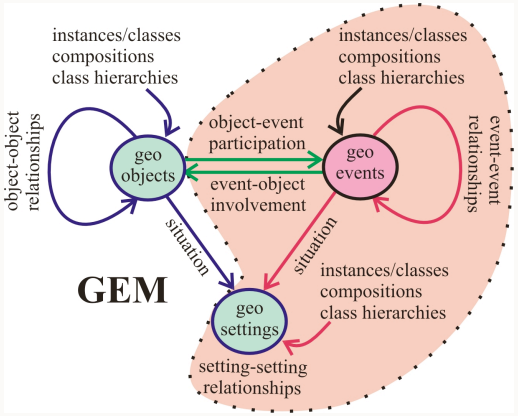




NOW FOR OUR PURPOSES...

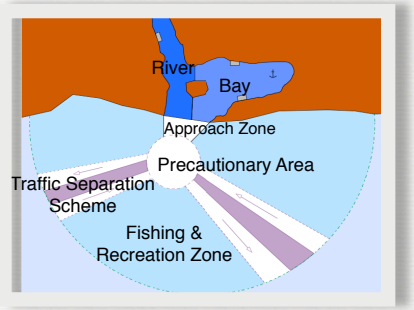
- **Continuants** *map to* **objects**
- **Occurrents** *map to* **events**
- **Both** are needed to model fully a dynamic system

GEOSPATIAL EVENTS MODEL (GEM) WORBOYS AND HORNSBY 2004



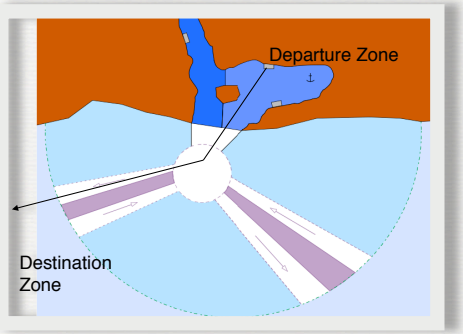
PROTOTYPICAL GEOSPATIAL DOMAIN *WITH STEPHEN COLE*

- A geospatial domain (e.g., a **harbor**) is partitioned into **zones**



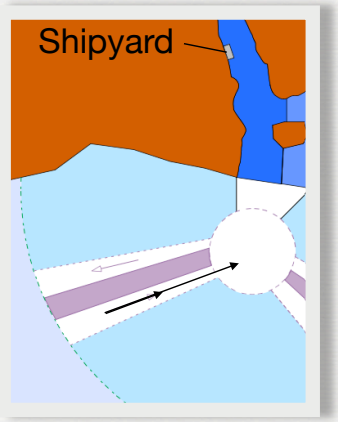
ZONES…

- A ***zone*** may be a ***departure*** or ***destination zone***.
- If a vessel heads for the sea from the harbor, the ***departure zone*** is the ***ferry landing*** and the ***destination zone*** is the ***offshore zone***.



MOVEMENT AS EVENTS

- The **movement** of an object across a zone boundary is modeled as a ***ChangeZoneEvent***
- $_{KWY}\ cze\ ^{precautionary}_{0230}$



SUCCESSIONS OF MOVEMENTS ARE MODELED AS SEQUENCES

- An **event sequence**, *E*, is defined as a set of events *e* that capture movements of an object,

$$\left\{ {}_{id}e^{zone}_{t1}, {}_{id}e^{zone}_{t2}, \ldots, {}_{id}e^{zone}_{tn} \right\} \text{ where,}$$

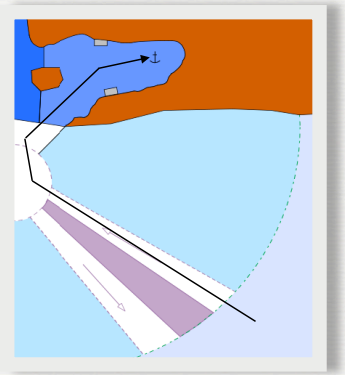
- $${}_{id}e^{zone}_{t1} < {}_{id}e^{zone}_{t2} < \ldots < {}_{id}e^{zone}_{tn}$$

  For any two events, one precedes the other

TRANSITS

- An event sequence that models an object's movement through a geospatial domain is referred to as a **transit**

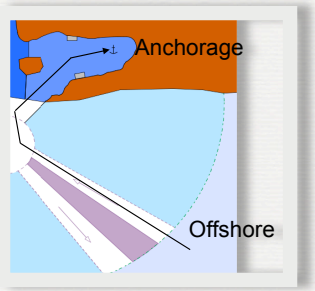
$$_{ID}T = \left\{ e \in E \,\middle|\, e.id = ID \right\}$$



$$_{FRY}cze^{inbd\_SE\_TSS}_{t1} < {}_{FRY}cze^{precautionary}_{t2} < {}_{FRY}cze^{approach}_{t3} <$$

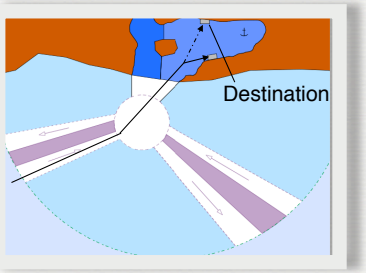
- $$_{FRY}cze^{bay}_{t4} < {}_{FRY}cze^{anchorage}_{t5}$$

TRANSITS CAPTURE SPECIAL KINDS OF MOVEMENTS



$$\underset{WFG}{oldZone:offshore}\ dep^{inbd\_SE\_TSS}_{t1} < {}_{WFG}cze^{precautionary}_{t2} < {}_{WFG}cze^{approach}_{t3} < {}_{WFG}cze^{bay}_{t4} < \underset{WFG}{expectedDest:anchorage}\ arr^{anchorage}_{t5}$$

- The transit is not ended with an ***arr*** event, but with an ***ude*** event



- $$\underset{FRB}{oldZone:\ offshore}\ dep\ {}^{inbd\_W\_TSS}_{t1} < {}_{FRB}\ cze\ {}^{precautionary}_{t2} < {}_{FRB}\ cze\ {}^{approach}_{t3}$$
$$FRB\ cze\ {}^{bay}_{t4} < \underset{}{expectedDest:\ ferryLanding}\ {}_{FRB}ude\ {}^{petroleumTerminal}_{t5}$$

NOTEWORTHY EVENTS

- This type of event is distinguished by comparing the movements associated with an object with the movements with the movements with which that object **is expected to be associated**…
  - E.g., an *UnexpectedZoneEvent uze* where,

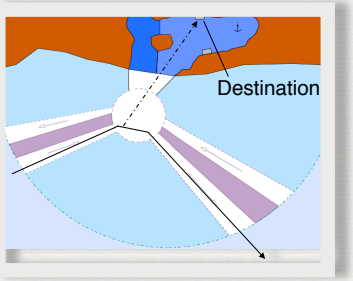
$$cze.zone \neq cze'.expectedNext$$

- And ***cze*** is the previous ***changeZoneEvent***
- ***UnexpectedDestinationEvent ude*** where an ***arr*** is expected at a certain destination zone but instead occurs at a different destination

ADDITIONAL SEMANTICS

- **Aborted Transit**

A vessel enters the harbor waters and then leaves again without ever reaching its intended destination



$$\underset{FRY1}{oldZone:\ offshore}\ dep^{inbd\_W\_TSS}_{t1} < \underset{FRY1}{}\ cze^{precautionary}_{t2} <$$
$$\underset{FRY1}{expectedNext:approach}\ uze^{outbd\_SE\_TSS}_{t3} < expectedDest:\ ferryLanding\ ude^{offshore}_{t4}$$

MIXTURE OF SEMANTICS

- Event sequences, therefore, can represent a **mixture of movement semantics** in a domain, modeling both
- **routine** and
- **noteworthy** (possibly unexpected) movements

MOVEMENT PATTERNS

- So far we have discussed **individual events** within a transit in order to model the semantics associated with particular movements of objects

In addition, the **pattern of movements** themselves can also be meaningful

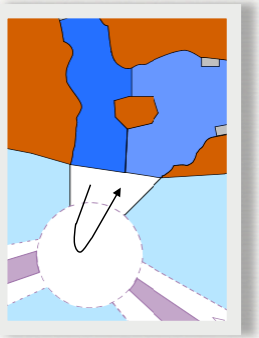
-

COLLOCATING PATTERN

- An unexpected reversal of a moving object reflected by events in the same zone

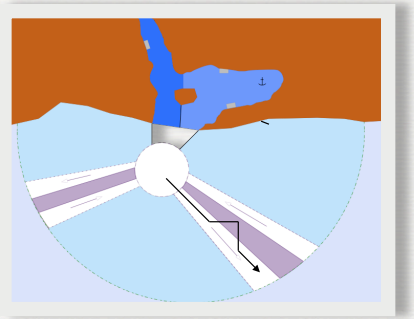
$$G\left(\left[e_1, e_2\right]\right) where\left(id_1 = id_2\right), \left(name_1 \neq name_2\right), \left(zone_1 = zone_2\right)$$

$$G\left(\left[{}_{RTN}\ cze^{\ approach}_{10:15}\ ,\ {}^{expectedNext:outbnd\_SW\_TSS}_{RTN}\ uze^{\ approach}_{10:55} \right] \right)$$



REPEATING PATTERN

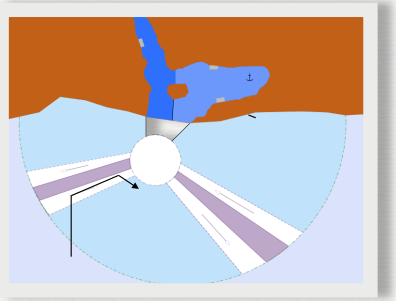
- The same event is experienced twice in the same zone



$$\ldots < {}_{L21}\,cze^{\,out\_SE\_TSS}_{20:30} < {}^{expectedNext:offshore}_{L21}\,uze^{\,sep\_SE\_TSS}_{20:45} < {}_{L21}\,cze^{\,out\_SE\_TSS}_{21:00} < \ldots$$

REPEATING PATTERN

- The same event is experienced twice in the same zone



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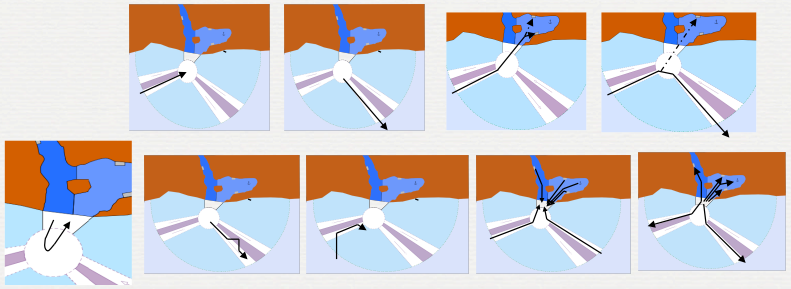
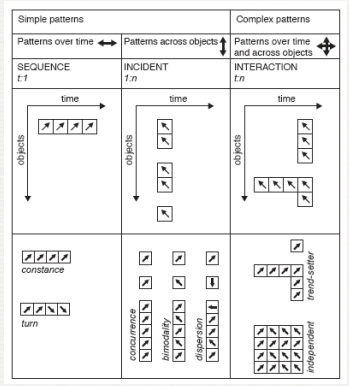
$$\ldots < \overset{expectedNext:inbd\_W\_TSS}{H13}\ uze\ \overset{S\_F\&R}{09:14} < \underset{H13}{}\ cze\ \overset{inbd\_W\_TSS}{09:32} <$$

$$\overset{expectedNext:precautionary}{H13}\ uze\ \overset{S\_F\&R}{09:48} < \ldots$$

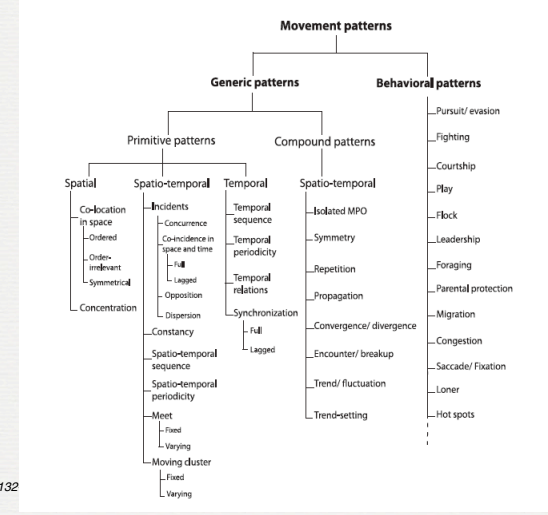
CLASSIFICATION OF MOVEMENTS



RELATIVE MOTION PATTERNS



Laube, P., and Imfeld, S. (2002) Proceedings of GIScience 2002, 132



Dodge, S., Weibel, R., and Lautenschütz, A-K. (2008) Towards a taxonomy of movement patterns, Information Visualization, 7, 240-252

WHAT'S NEXT?

- So far we have been modeling total orders of events
- focus on ***before*** and ***after*** relation
- Creates temporal and spatial patterns of event common for simulations

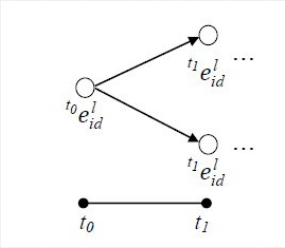
BRANCHING EVENTS MODEL

WITH SHANE HUBBARD

- Extend this research to capture **multiple possibilities**
- For example, what might happen in the **future** or what might have happened in the **past**
- Useful for emergency response, public safety, spatial decision support

BRANCHING: DIVERGENCE

- **Divergence**
- A key element of branching
- **After an initial event,** two more are possible
- recursive



BRANCHING:CONVERGENCE

- **Convergence**
- Where **prior to an event,** two or more events are possible
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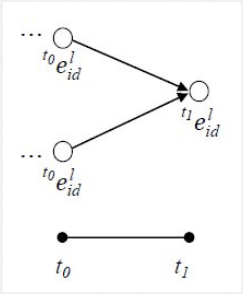
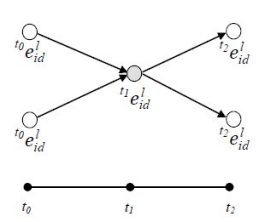


COMBINING ALL ELEMENTS

- Both converging and diverging can be **combined**



SUMMARY

- Have been considering **spatiotemporal semantics** associated with moving objects
- Different kinds of **events**
  - routine, noteworthy, unexpected…
- Different classes of **paths** of **moving objects**
- Extend underlying temporal model to support **branching events**
-

QUESTIONS?