Ministério da
Ciência e Tecnologia

Spatio-Temporal Database

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Topics

(1) Spatio-temporal Data and Applications

(2) Representation of Spatio-Temporal Data

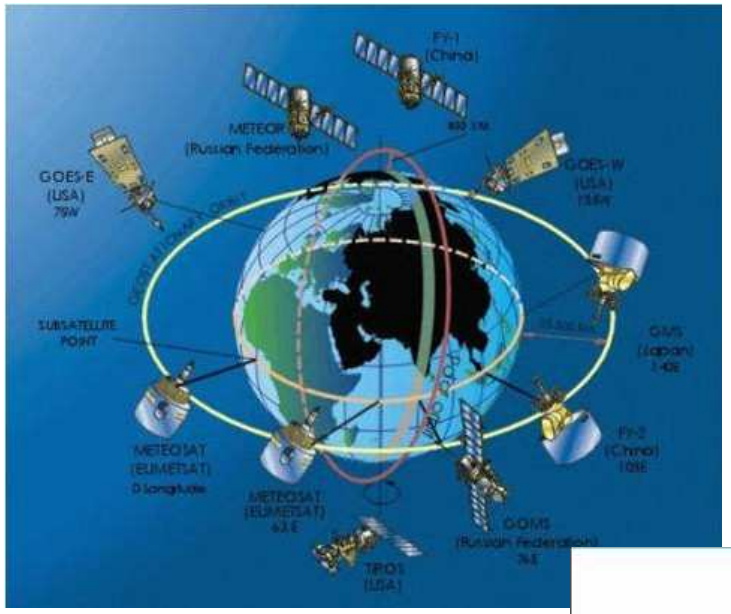
- (a) Existing Spatio-Temporal Database Models

(3) Spatio-Temporal Database Systems

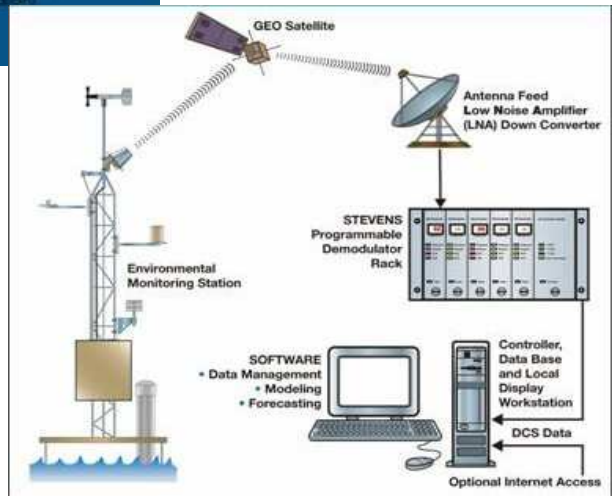
Spatio-temporal Data and Applications

Spatio-temporal Data

Technological advances in geospatial data collection.



Earth observation and GPS satellites

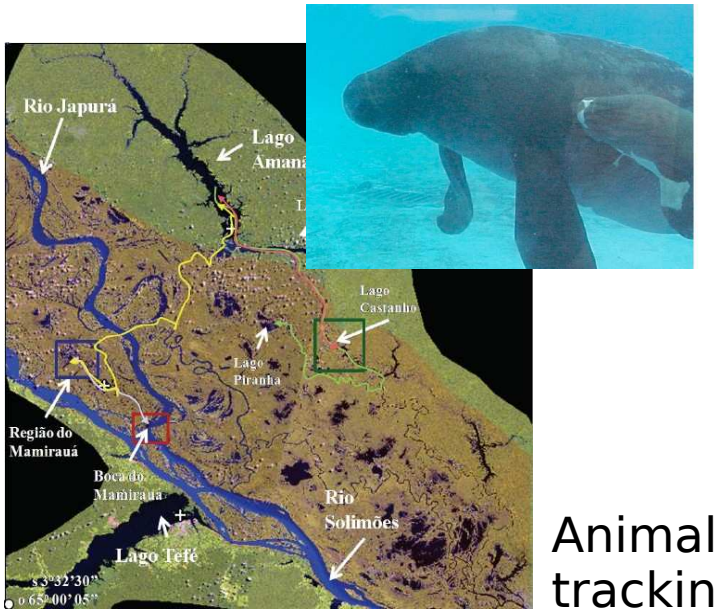


wireless and mobile computing, radio-frequency identification (RFIDs) and sensor networks

Spatio-temporal Data

Technological advances in geospatial data collection.

Applications which handle dynamic geospatial information



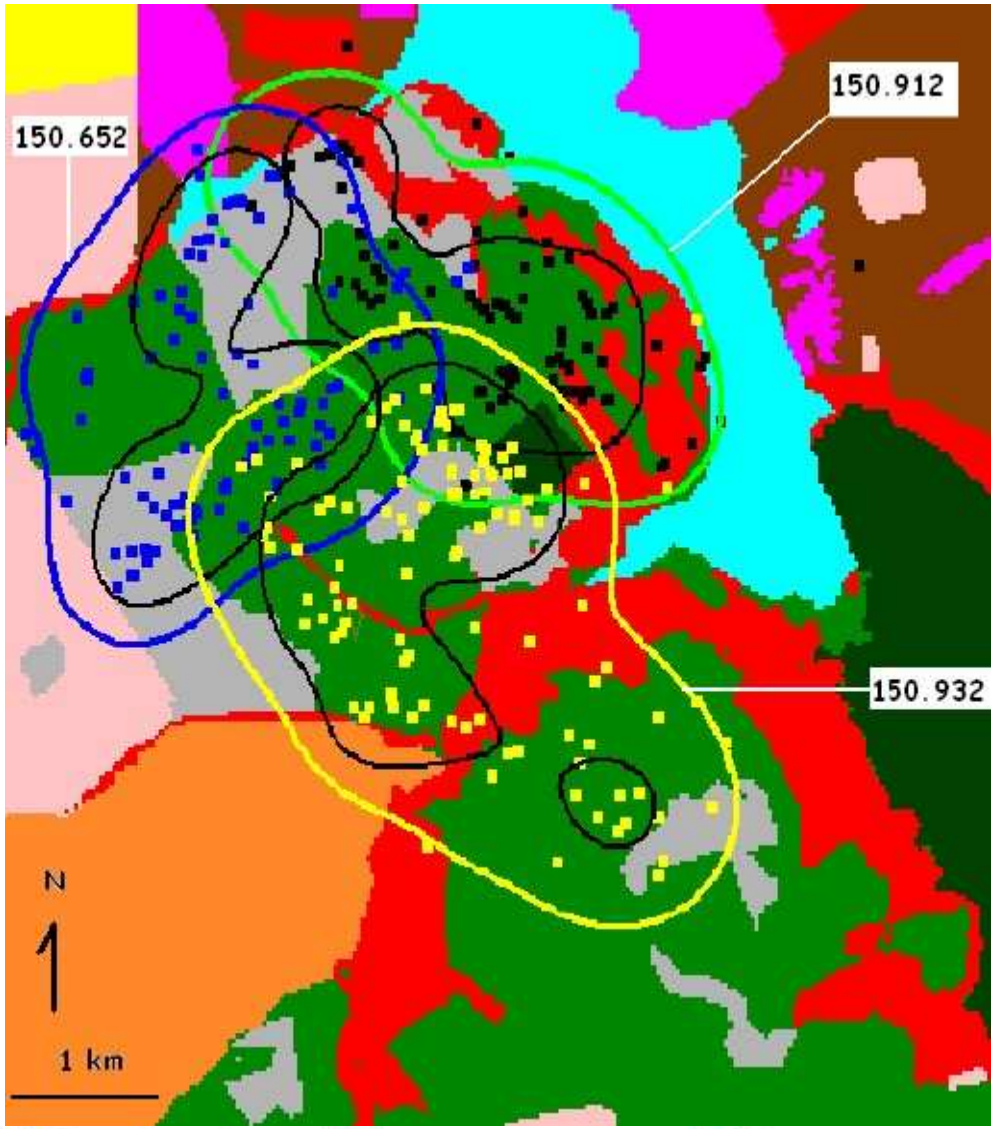
[Arraut, E. M. 2008]

Animal tracking monitoring

oil spill on the ocean

hurricane and volcanic eruption monitoring

Spatio-temporal Data and Applications



Levantamento, área de vida, uso e seleção de habitat de **Aves de Rapina** na região central do estado de São Paulo.

Julho de 2005 a junho de 2007 - monitorando 6 aves de rapina por rádio-telemetria.

Mapa de Uso e Ocupação do Solo

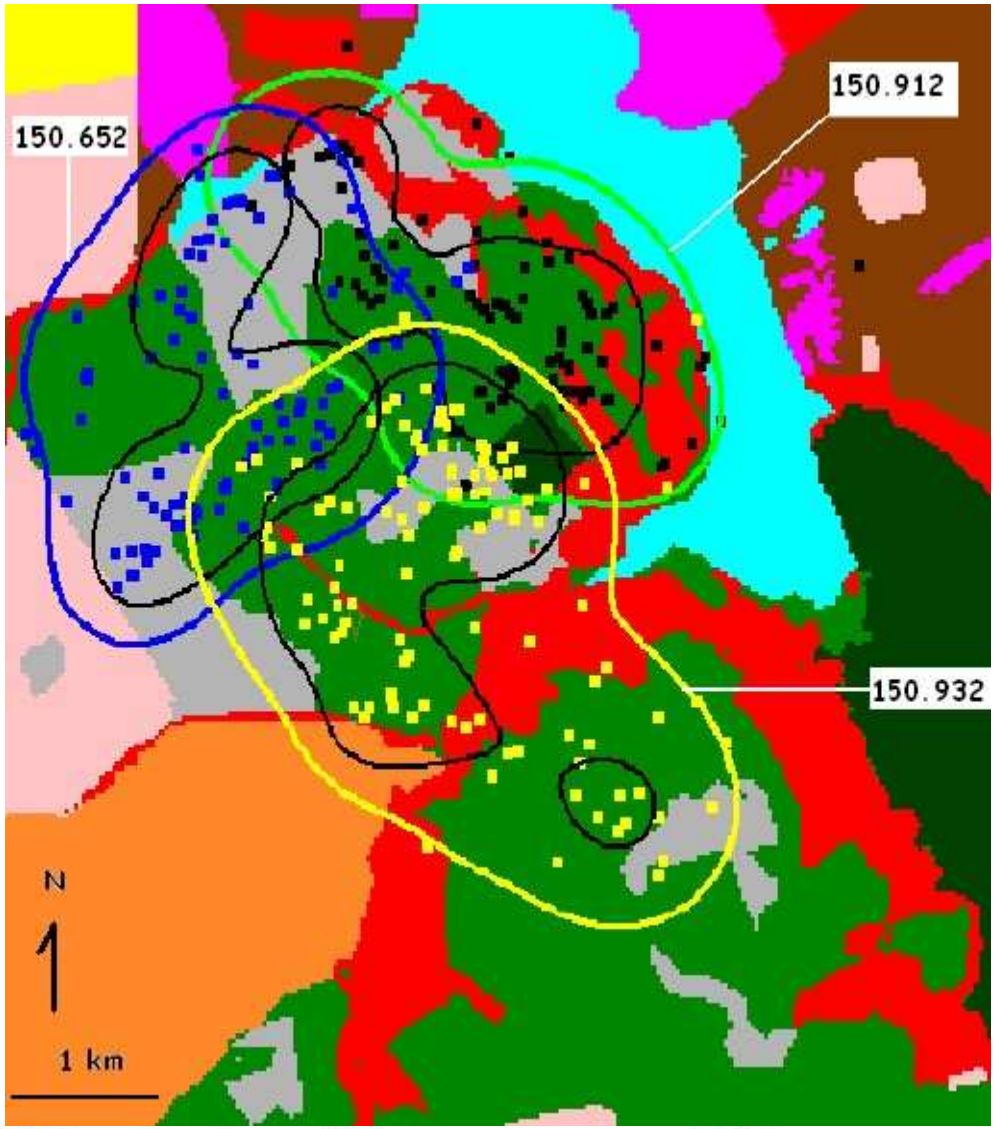
X

Trajetórias Dos Animais

Cana-de-açúcar
Formação florestal
Pastagem
Laranja
Urbanização
Campo cerrado
Outros cultivos
Cerrado aberto
Eucalipto
Água
Pinus

[Marco Granzinolli, 2009]

Spatio-temporal Data and Applications



Todos os dados geo-espaciais estão variando ao longo do tempo: Uso e Ocupação do Solo (***geo-field***) e Localizações dos animais (***geo-object***).

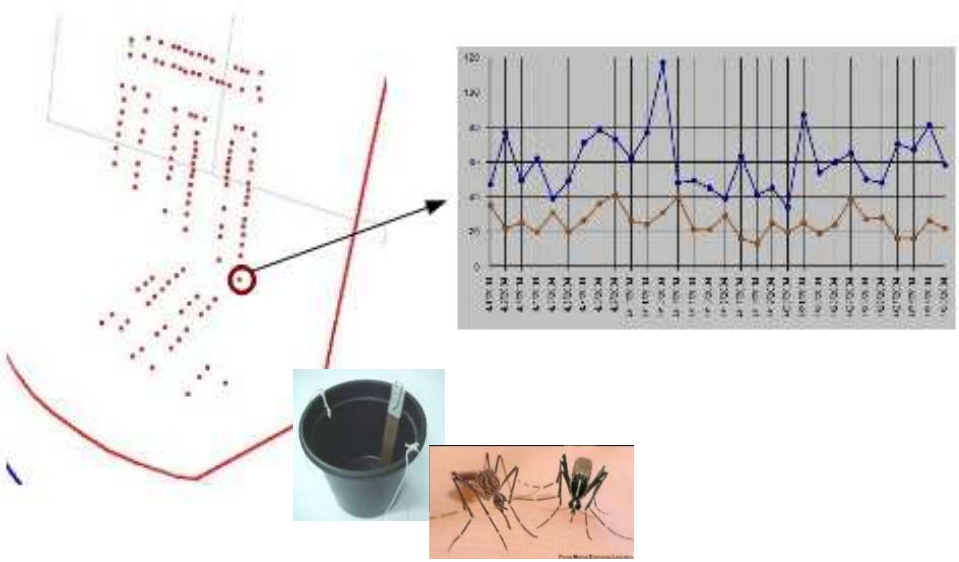
"Quanto tempo o animal 150.652 permaneceu em cada uso e ocupação do solo?"

"Em quais momentos o animal 150.652 sai do cerrado aberto e entra no campo cerrado"

[Marco Granzinolli, 2009]

Spatio-temporal Data and Applications

SAUDAVEL



“Which month had the biggest number of infected eggs?”

“When and where were more than 80 infected eggs collected by each trap? ”

[Monteiro et. al., 2009]

[INPE’s Antarctica Program, 2010]

“When and where did objects o1 and o2 meet each other (considering a meeting when the distance between two objects is less than 2 meters)?”

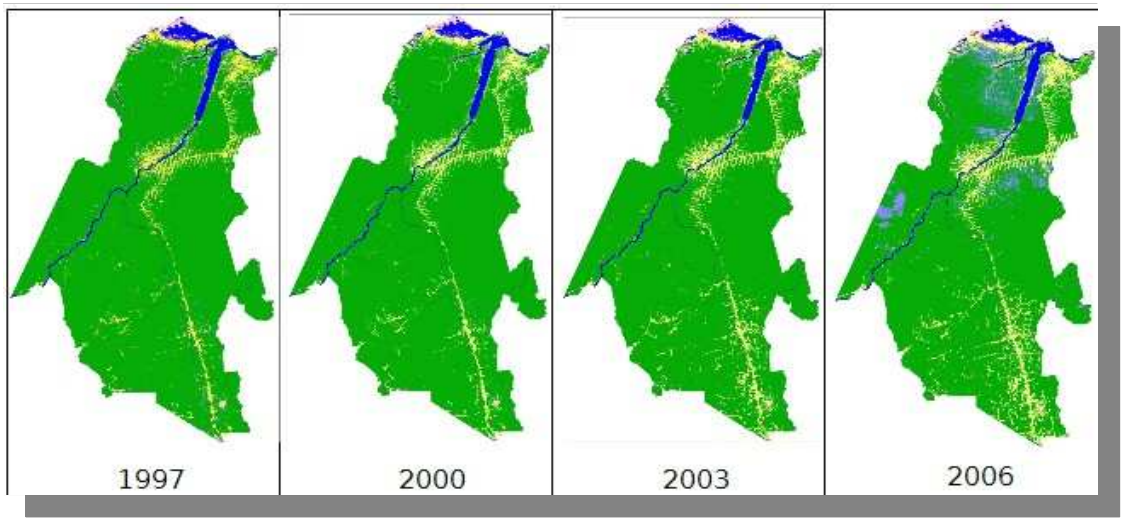
“Where and when was there a spatio-temporal cluster of objects?”

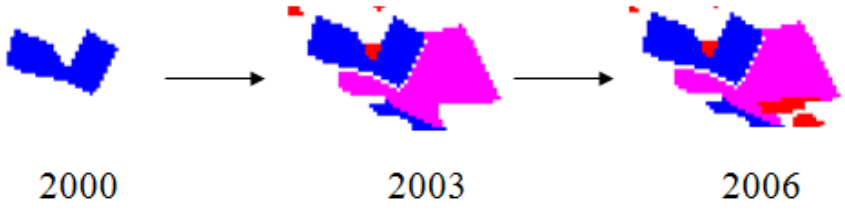
Movement Monitoring

Spatio-temporal Data and Applications

PRODES

Imagens Classificadas





Polígonos de Desmantamento

"*How was the state of a specific deforested region in 2002? (considering that this specific deforested region was not observed in 2002)?*"

"*how did a specific deforested region evolve over time between 2000 and 2008?*"

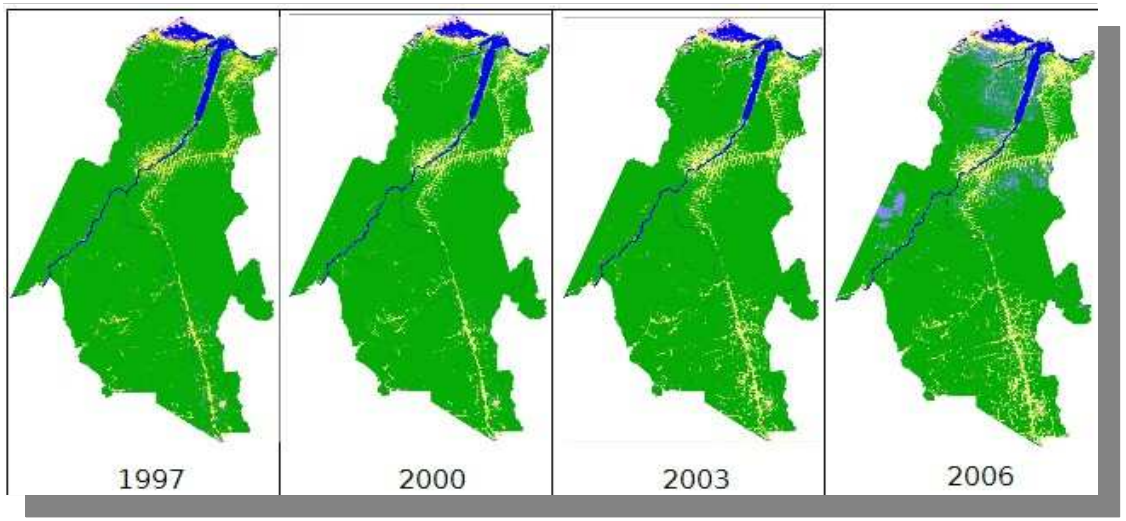
"*how did the deforested regions that started less than 2 kilometer far from the river r1 evolve over time?*"

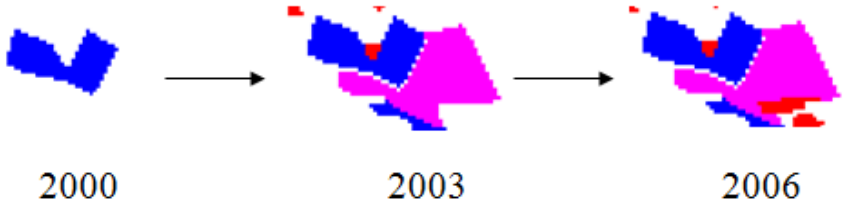
"*when did a specific deforested region reach the municipality x?*"

Spatio-temporal Data and Applications

PRODES

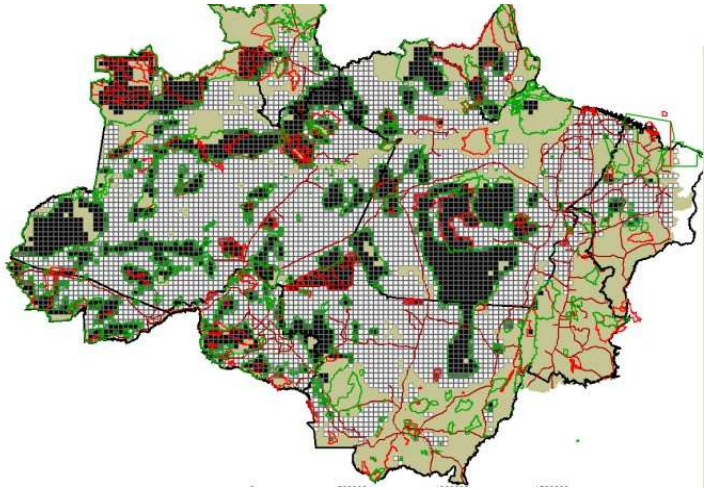
Imagens Classificadas





Polígonos de Desmantamento

Land Use and Land Cover Modeling

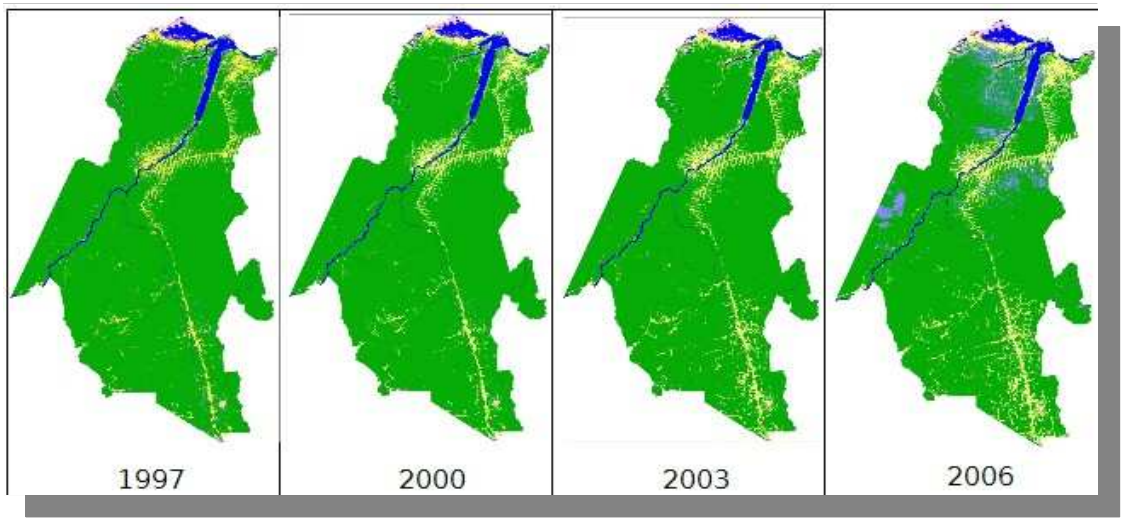


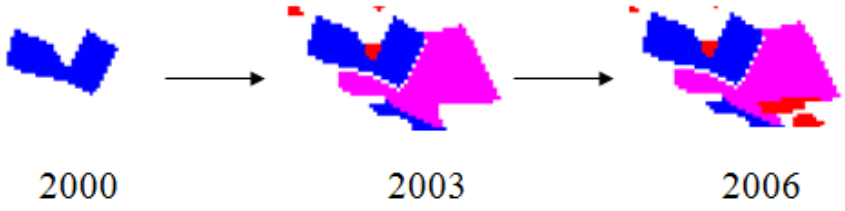
"given a cell, how has the forest status been varying in this cell over time?"

Spatio-temporal Data and Applications

PRODES

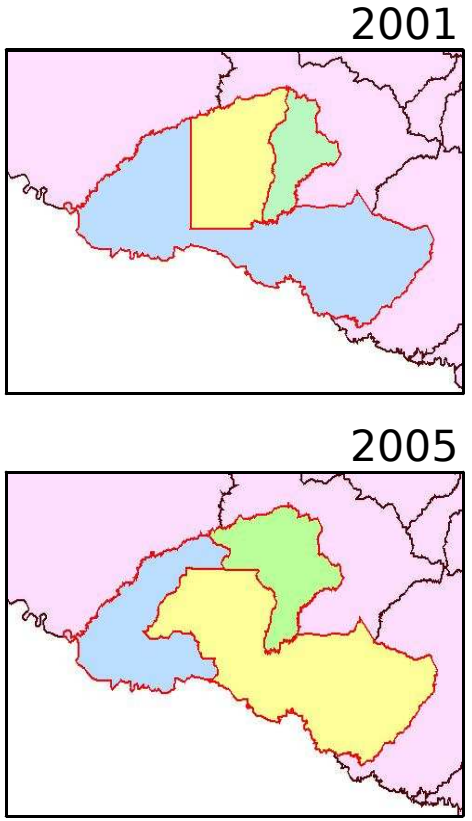
Imagens Classificadas





Polígonos de Desmantamento

Municipal Management

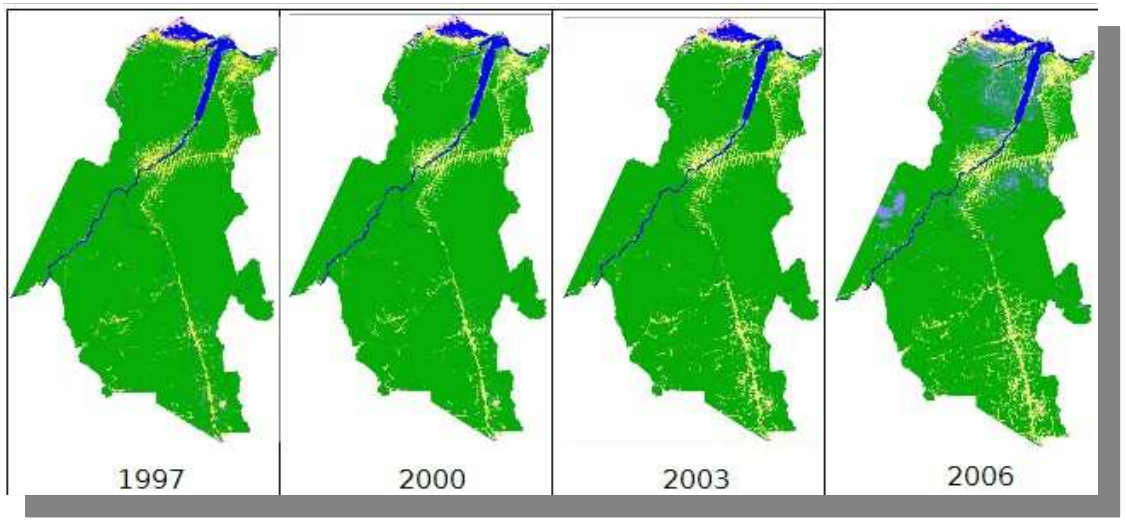


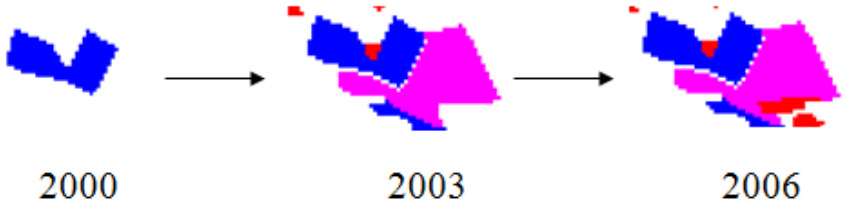
"How many hectares were deforested in each municipality? "

Spatio-temporal Data and Applications

PRODES

Imagens Classificadas





Polígonos de Desmantamento

Descobrir **padrões** de áreas desmatadas e como esses padrões evoluem no tempo:

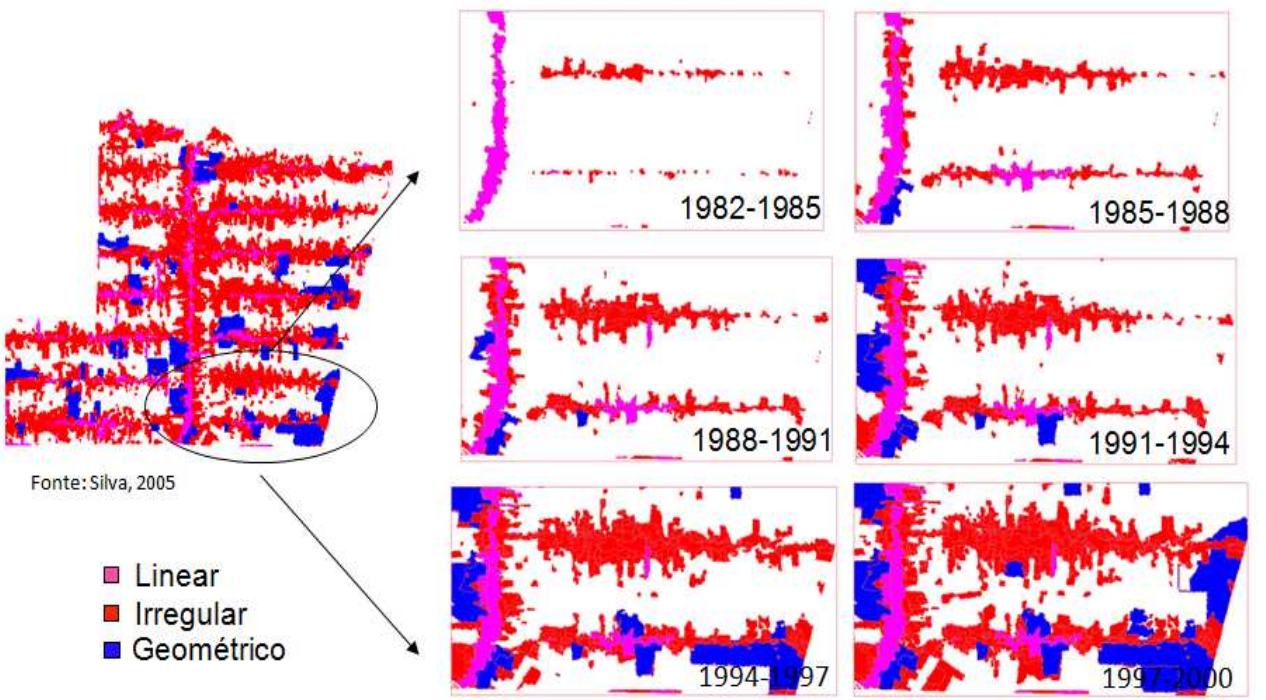
*é importante ter o conceito de **objeto** (área desmatada) e de **evolução desse objeto** ao longo do tempo.*

[Silva et al., 2005]

[Motta et al., 2009]

[Bittencourt et al., 2008]

Spatio-temporal Data and Applications



Descobrir **padrões** de áreas desmatadas e como esses padrões evoluem no tempo:

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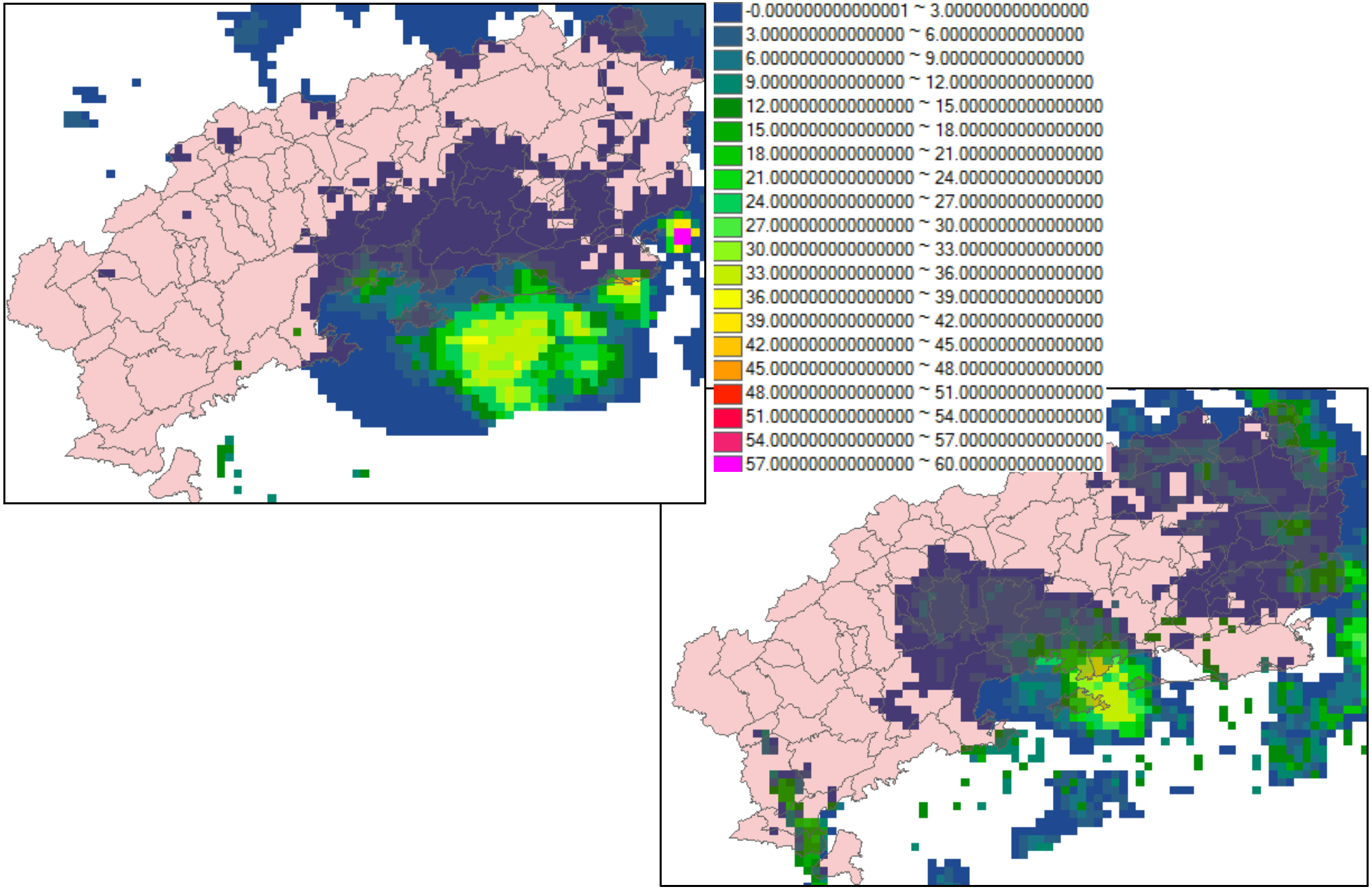
Spatio-temporal Data and Applications



Spatio-temporal Data

Regarding spatio-temporal data, there are many distinct research areas in geographical information (GI) science:

Representation and Query of Spatio-Temporal Data

Indexing of Spatio-Temporal Data

Analysis of Spatio-Temporal Data

Spatio-Temporal Data Mining and Pattern Recognition

Spatio-Temporal Visualization

Spatio-temporal Data

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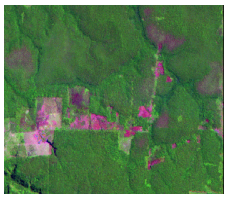
Spatio-Temporal Data Mining and Pattern Recognition

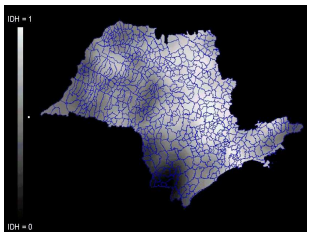
Spatio-Temporal Visualization

Representation of Spatio-Temporal Data in Computational Systems

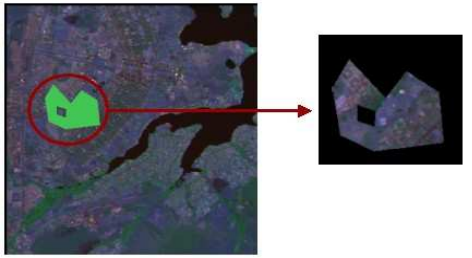
Representation of Spatial Data

Static geospatial information is represented in GIS following well-established ideas.

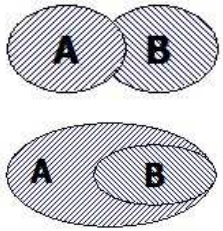


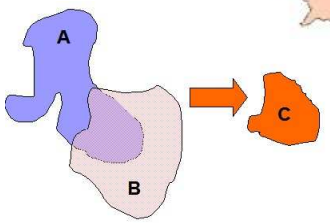


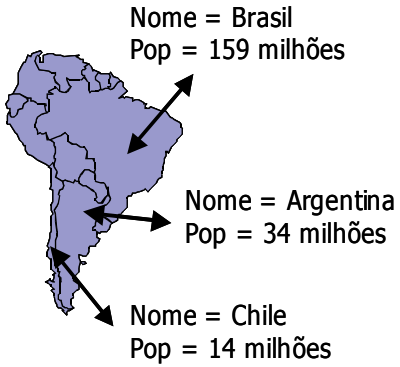
Geo-Fields and Geo-Objects



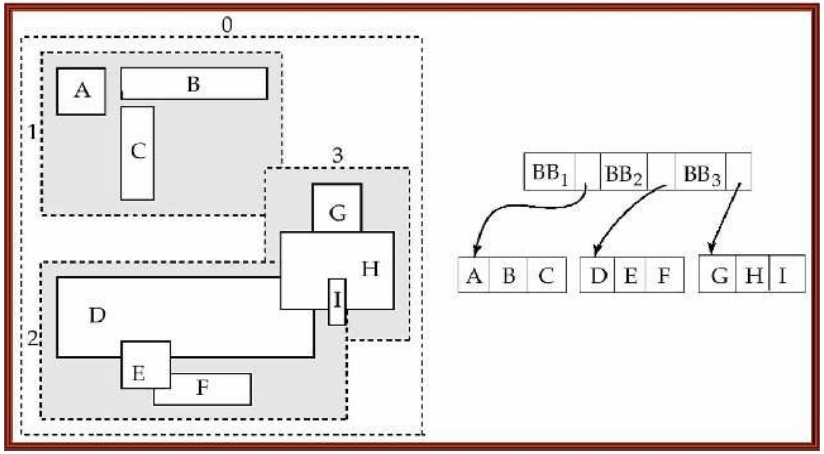
Spatial Operations







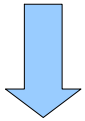
Spatial Index



The majority of GIS and spatial DBMS is based on these ideas and concepts!

Representation of Spatio-Temporal Data

Static geospatial information is represented in GIS following well-established ideas.



There is no consensus on how to represent dynamic geospatial information in computational systems.

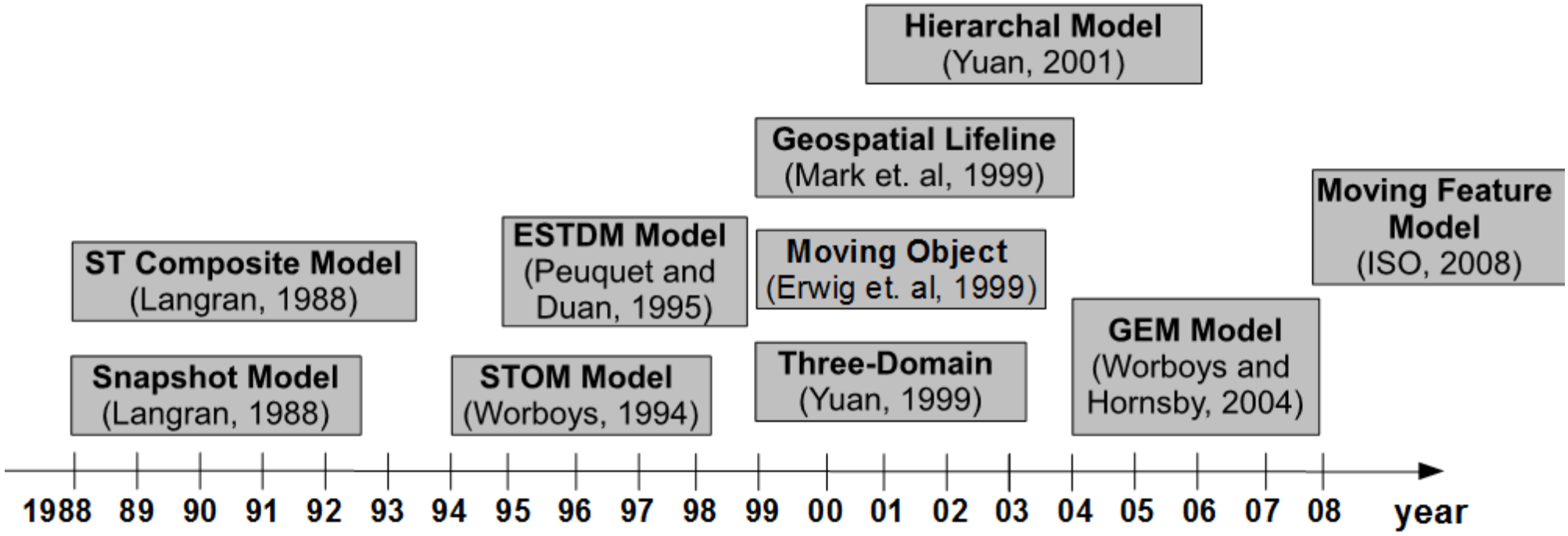
Spatial information: every **spatial DBMS** (ex.: Oracle Spatial and PostGIS) follows a pattern to represent and query spatial information (**SFS-OGC**).

And spatio-temporal information?

"There are four stages in introducing temporal capacity into GIS: (0) static GIS, (1) temporal snapshots, (2) object change, and (3) events, actions and processes. Most current proprietary technologies are in stage zero..." [Worboys, 2005]

Existing Spatio-Temporal Database Models

There are many proposals of spatio-temporal database models.

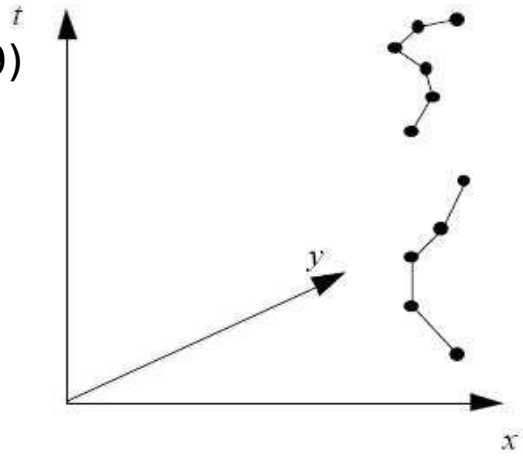


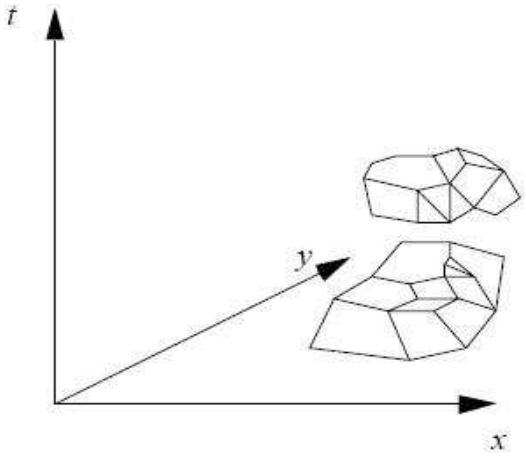
Existing Spatio-Temporal Database Models

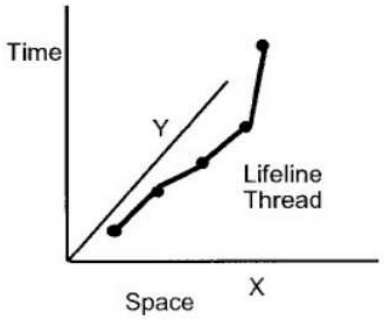
There are many proposals of spatio-temporal database models.

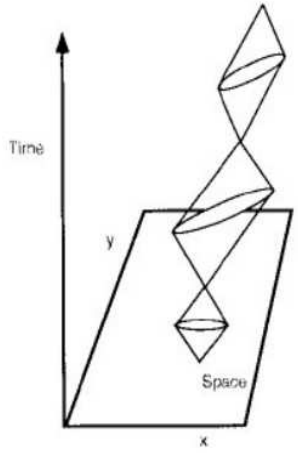
Moving Object (Erwig et. al, 1999)

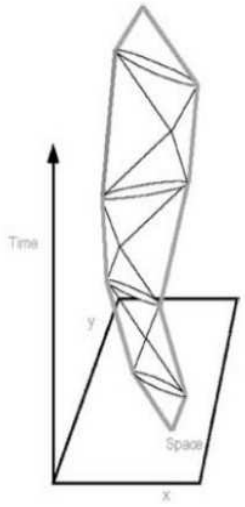
- Algebra: data types and operations for objects in movement
- Levels of abstraction: Abstract and Disc
- SECONDO
- Not consider fields varying over time.
- Only consider linear trajectory.







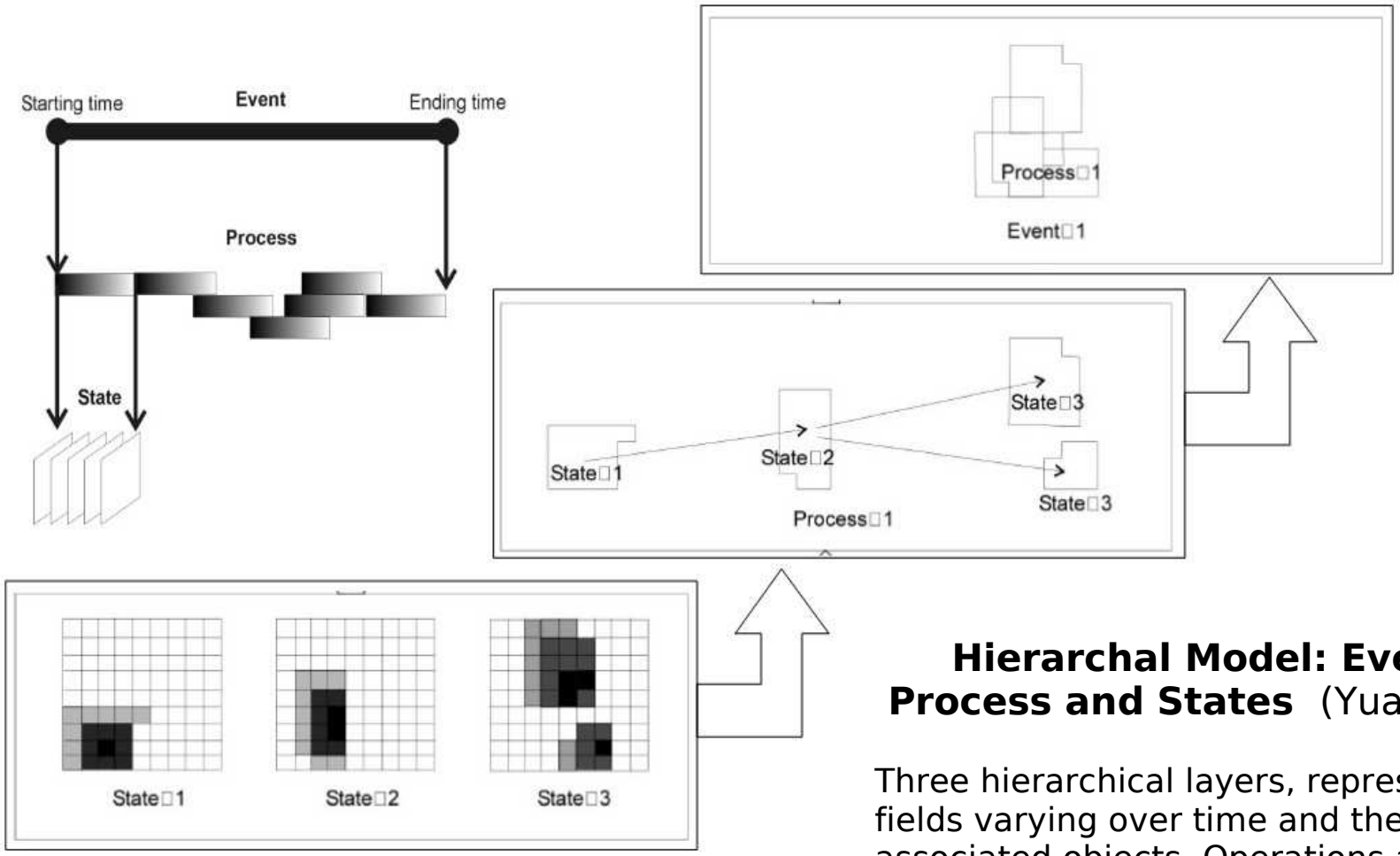




Geospatial Lifeline
(Mark et. al, 1999)
Different types of trajectories.

Existing Spatio-Temporal Database Models

There are many proposals of spatio-temporal database models.

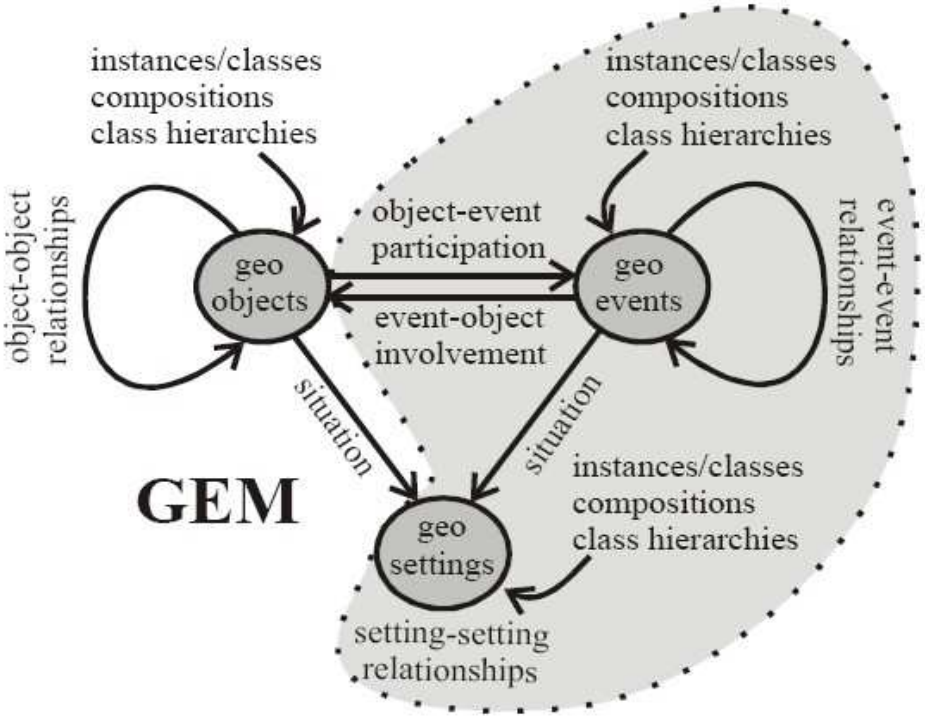


Hierarchal Model: Events, Process and States (Yuan, 2001)

Three hierarchical layers, representing fields varying over time and theirs associated objects. Operations are done over fields and objects.

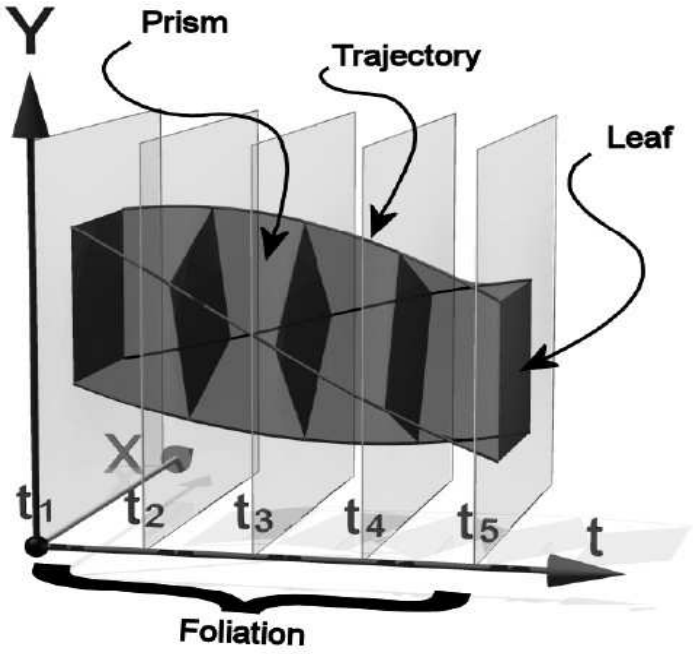
Existing Spatio-Temporal Database Models

There are many proposals of spatio-temporal database models.



Geospatial Event Model
(Worboys and Hornsby, 2004)

Relationships between objects and events and between events and events.

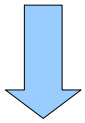


Moving Feature Model (ISO, 2008)

Do not consider feature geometry deformation and changes in non-spatial attributes.

Existing Spatio-Temporal Database Models

There are many proposals of spatio-temporal database models.



BUT ...

"*A serious weakness of existing spatio-temporal models is that each of them deals with few common features found across a number of specific applications*." [Pelekis at al. 2004]

Representation of Spatio-Temporal Data

Geo-Object which change over time			**Geo-Field which vary over time**
geometry is fixed and non-spatial attributes change over time	**geometry changes discretely over time** and non-spatial attributes also can change.	**geometry changes continuously over time** and non-spatial attributes also can change.	
Examples: - SAUDAVEL: egg traps - LUCC Modeling: cell space	Examples: - Municipal limit changes	Examples: - Movement monitoring (ex.: Aves de rapina e elefante marinho) - PRODES: Evolution of deforested areas	Examples: - PRODES: classified images - Land Use and Land Cover Maps

Representation of Spatio-Temporal Data

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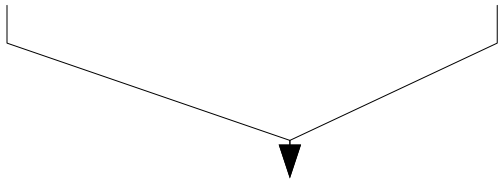
(a)	(b)	(c)	(d)



Difference between (b) and (c) is pointed out by Galton [2004] and Guting and Schneider [2005]

fiat objects → sudden changes

bona fide objects → gradual changes

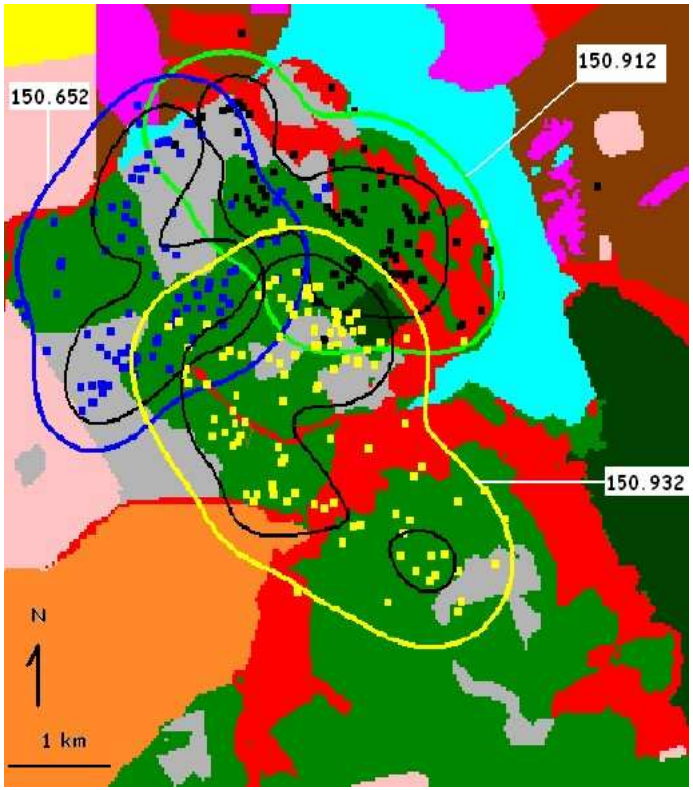
moving object model → continuous geometry changes

other models → discrete geometry changes

Representation of Spatio-Temporal Data

Geo-Object which change over time			**Geo-Field which vary over time**
geometry is fixed and non-spatial attributes change over time	**geometry changes discretely over time** and non-spatial attributes also can change.	**geometry changes continuously over time** and non-spatial attributes also can change.	
	1. ST Composite Model [Langran, 1988] 2. STOM Model [Worboys, 1994] 3. Three-Domain Model [Yuan, 1999] 4. GEM Model [Worboys and Hornsby, 2004]	1. Geospatial Lifeline [Mark et. al, 1999] 2. Moving Object [Erwing et. al, 1999] 3. Moving Feature Model [ISO, 2008]	1. Snapshot Model [Langran, 1988] 2. ESTDM Model [Peuquet and Duan, 1995] 7. Hierarchal Model [Yuan, 2001]

Representation of Spatio-Temporal Data



What model can we use to support (represent and query) this application? What model is able to represent and query geo-fields as well as geo-objects which change over time?

Hierarchal Model (Yuan, 2001)

Geospatial Lifeline (Mark et. al, 1999)

Moving Feature Model (ISO, 2008)

ESTDM Model (Peuquet and Duan, 1995)

Moving Object (Erwig et. al, 1999)

ST Composite Model (Langran, 1988)

GEM Model (Worboys and Hornsby, 2004)

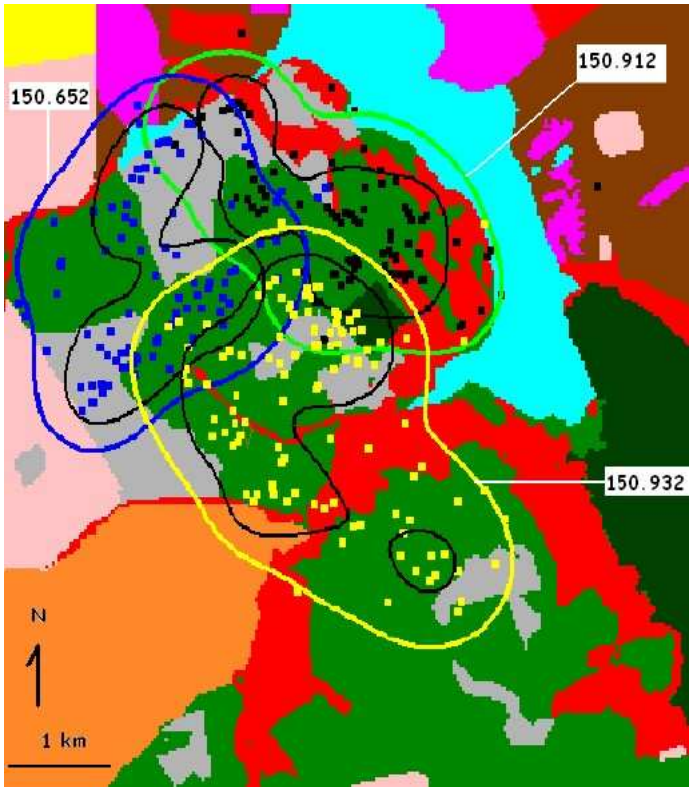
Three-Domain (Yuan, 1999)

Snapshot Model (Langran, 1988)

STOM Model (Worboys, 1994)

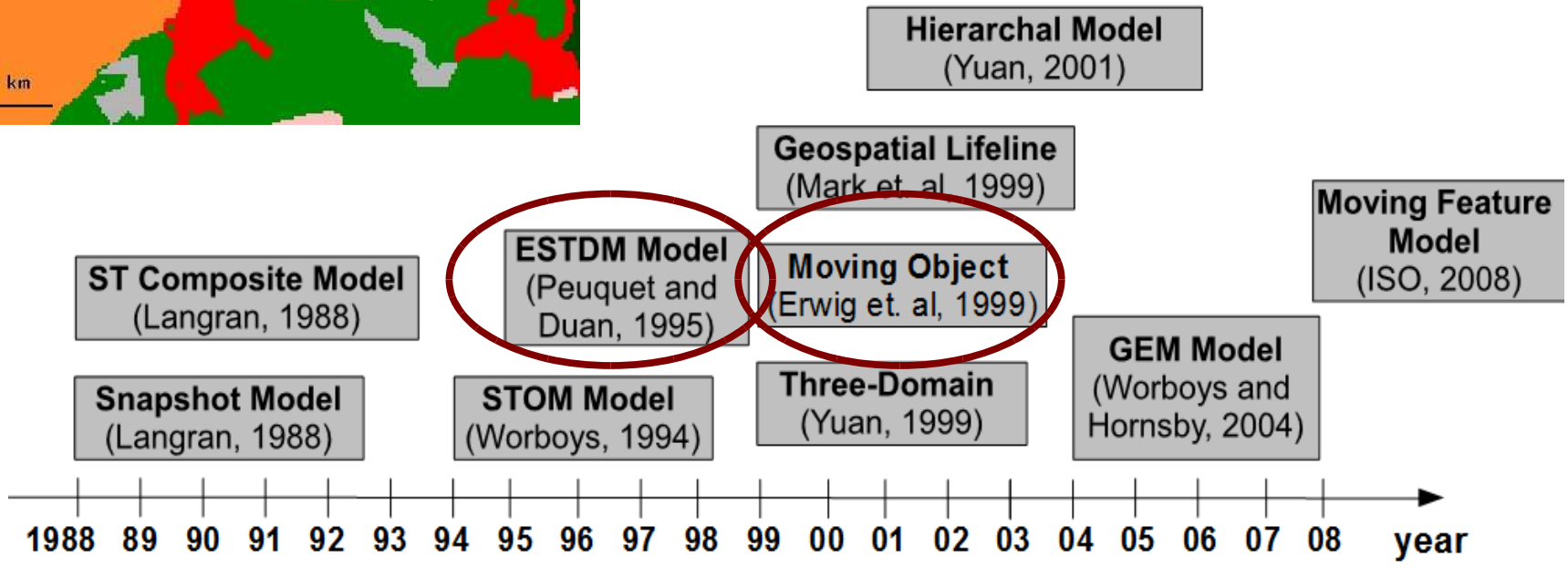
1988 89 90 91 92 93 94 95 96 97 98 99 00 01 02 03 04 05 06 07 08 year

Representation of Spatio-Temporal Data



(1) ESTDM [Peuquet and Duan, 1995] → Variação do uso e cobertura do solo.

(2) Moving Object [Erwing et, al, 1999] → Trajetórias dos animais



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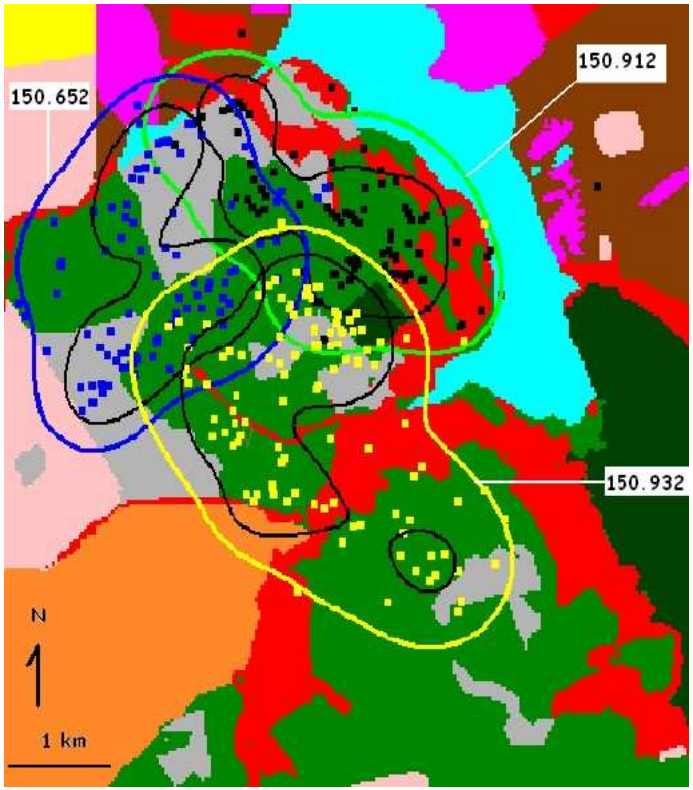


(1) ESTDM [Peuquet and Duan, 1995] → Variação do uso e cobertura do solo.

(2) Moving Object [Erwing et, al, 1999] → Trajetórias dos animais

How to answer these questions?

"Quanto tempo o animal 150.652 permaneceu em cada uso e ocupação do solo?"

"Em quais momentos o animal 150.652 sai do cerrado aberto e entra no campo cerrado"

Spatio-Temporal Database Systems

Spatio-Temporal Database Systems

(1) SECONDO

(2) HERMES – Oracle Spatial

SECONDO: Moving Object Database

- SECONDO: A Database System for Moving Objects

(http://dna.fernuni-hagen.de/Secondo.html/index.html)

- A prototype developed by University of Hagen, Germany

- Able to represent, store and query objects which move over time.

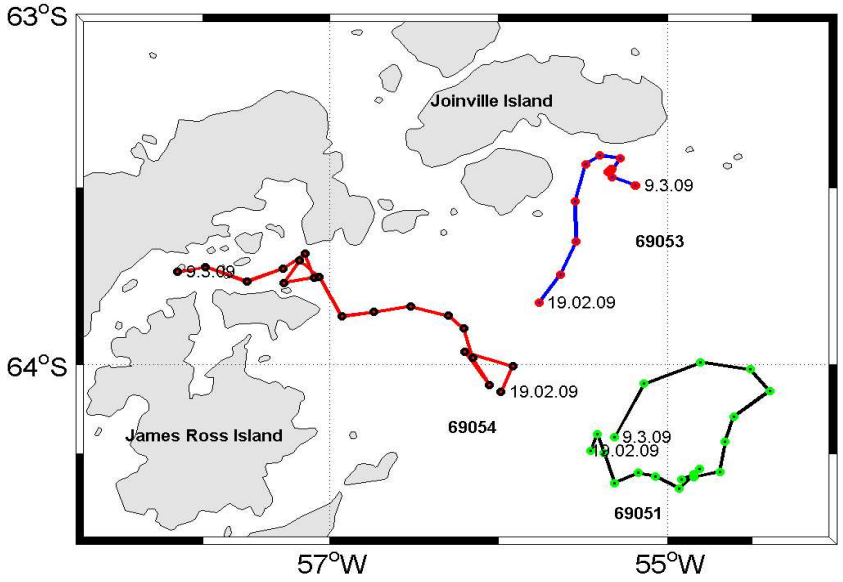
SECONDO: Moving Object Database

Moving Points (ex.: animais, veiculos e pessoas)

Moving Regions (ex.: mancha de oleo)

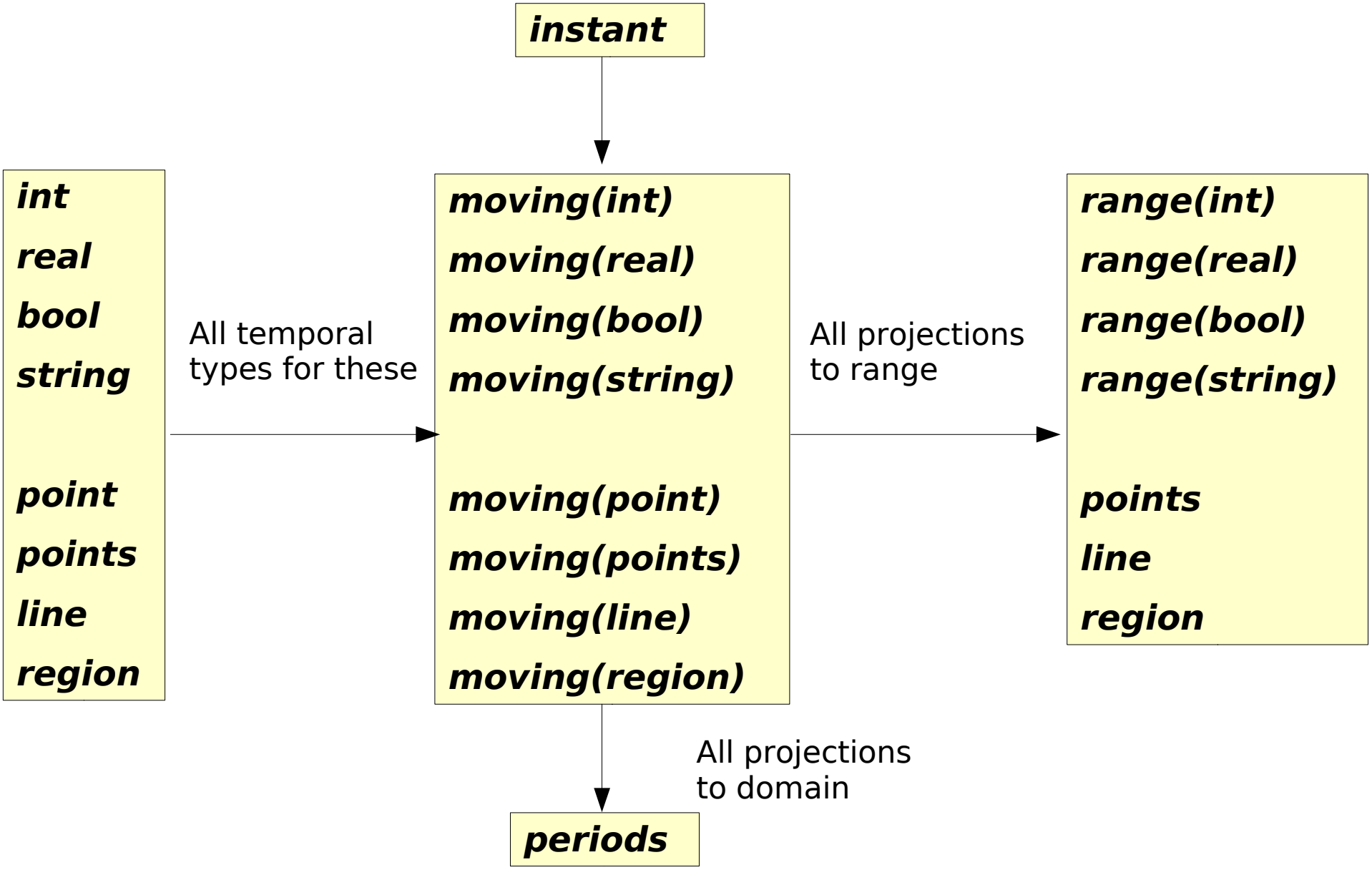
oil spill on the ocean

Animal tracking monitoring

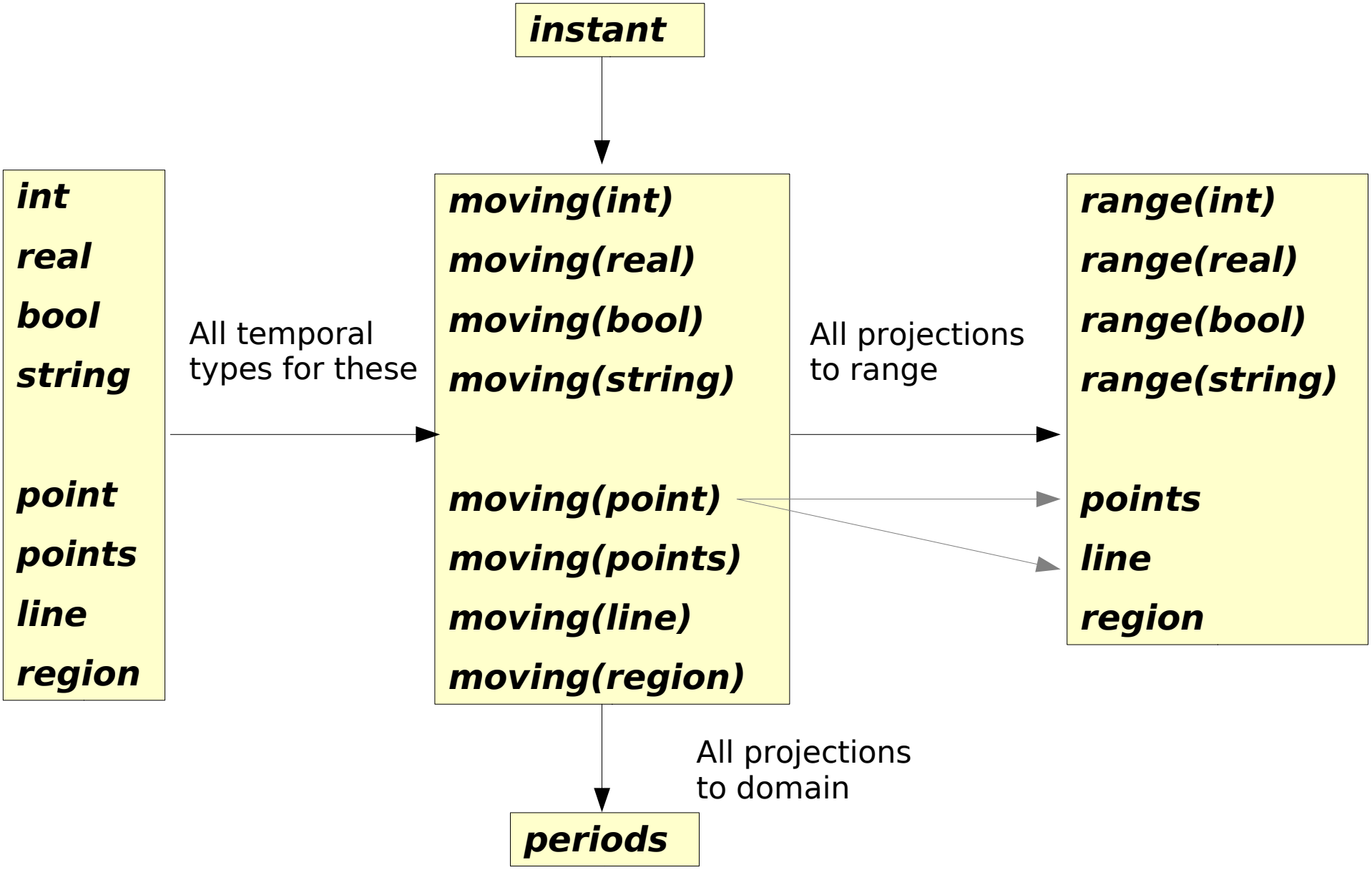


Iceberg tracking monitoring in Antarctica - SOS-Climate

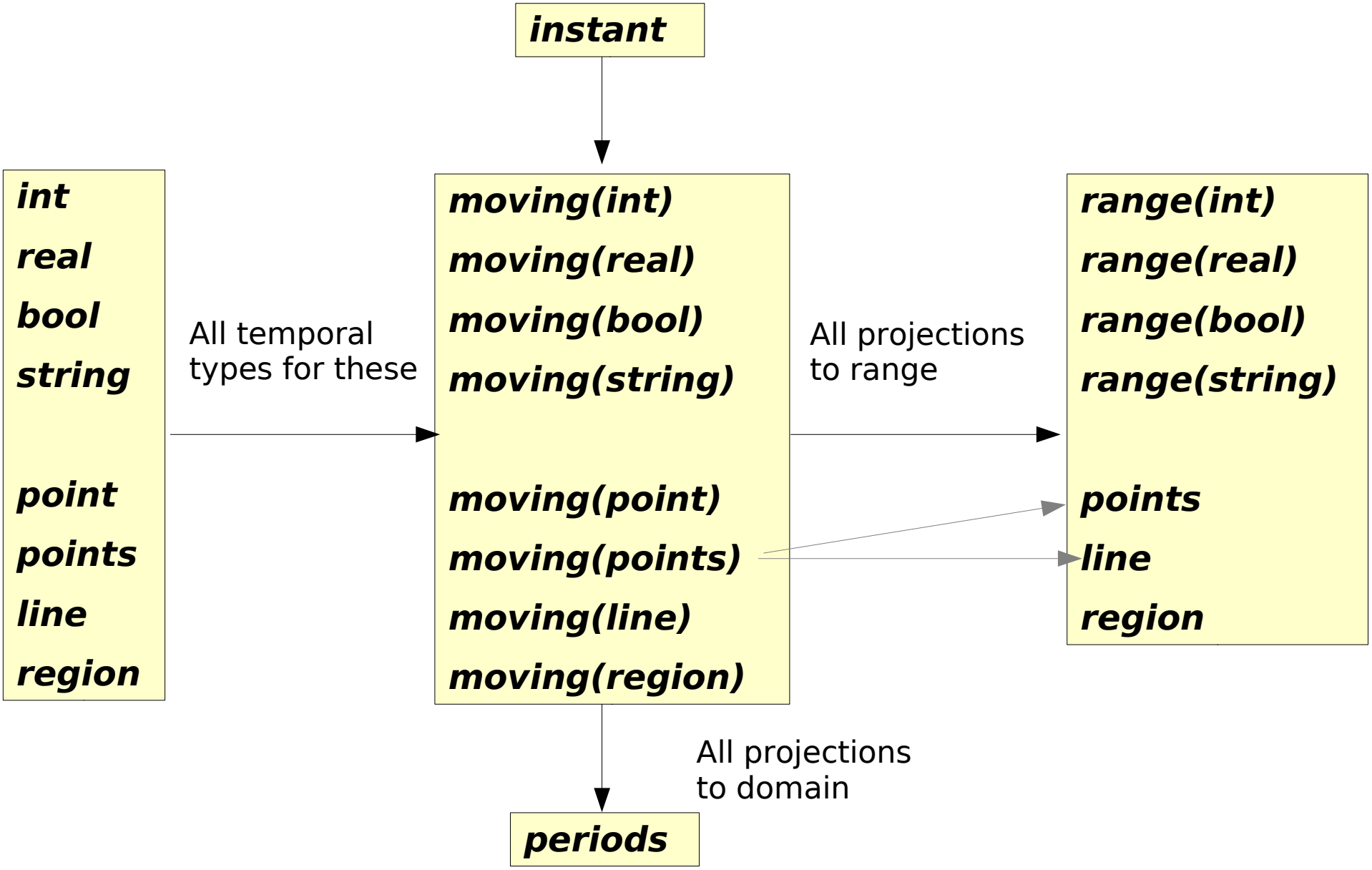
SECONDO: Moving Object Algebra



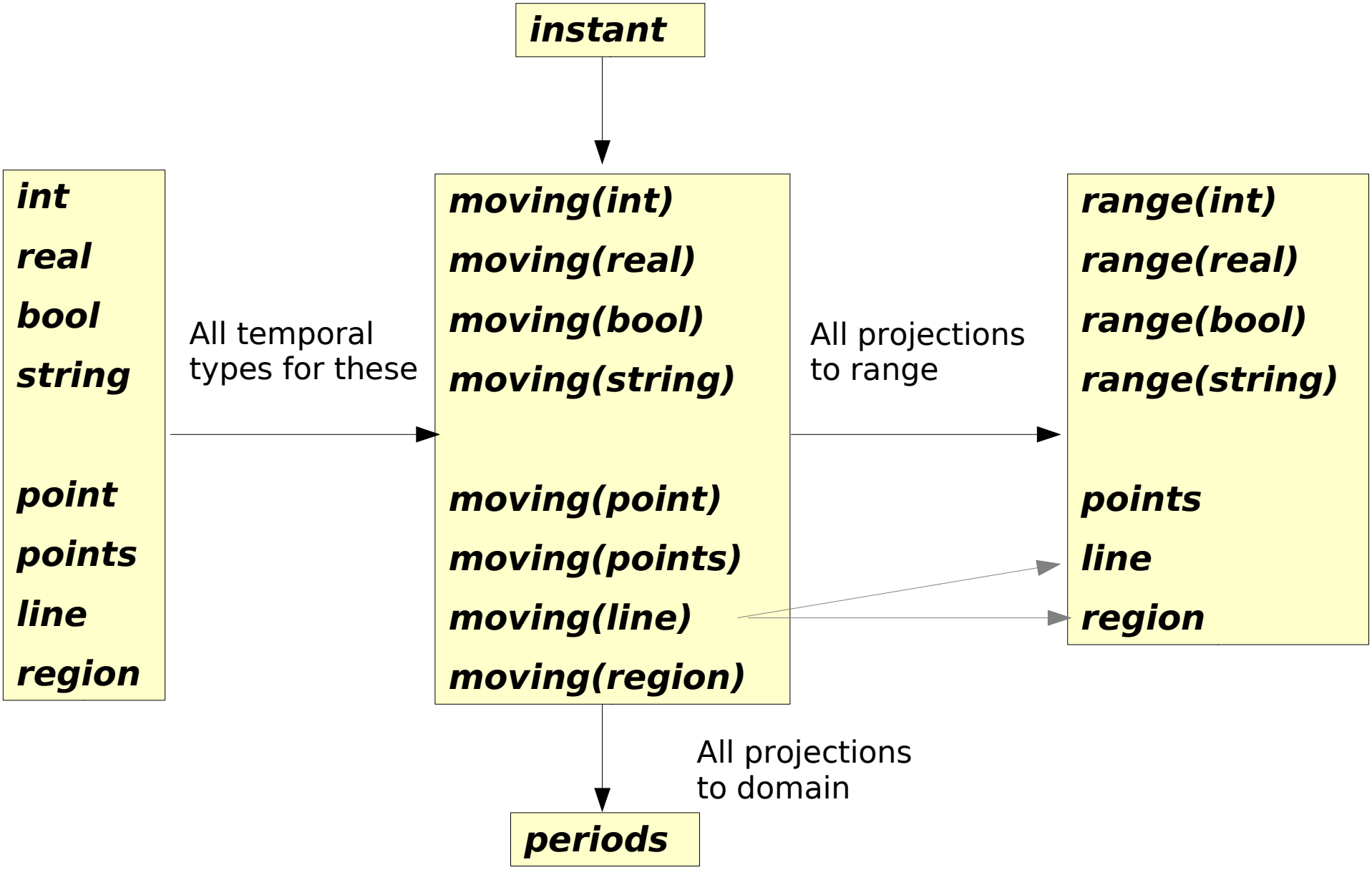
SECONDO: Moving Object Algebra



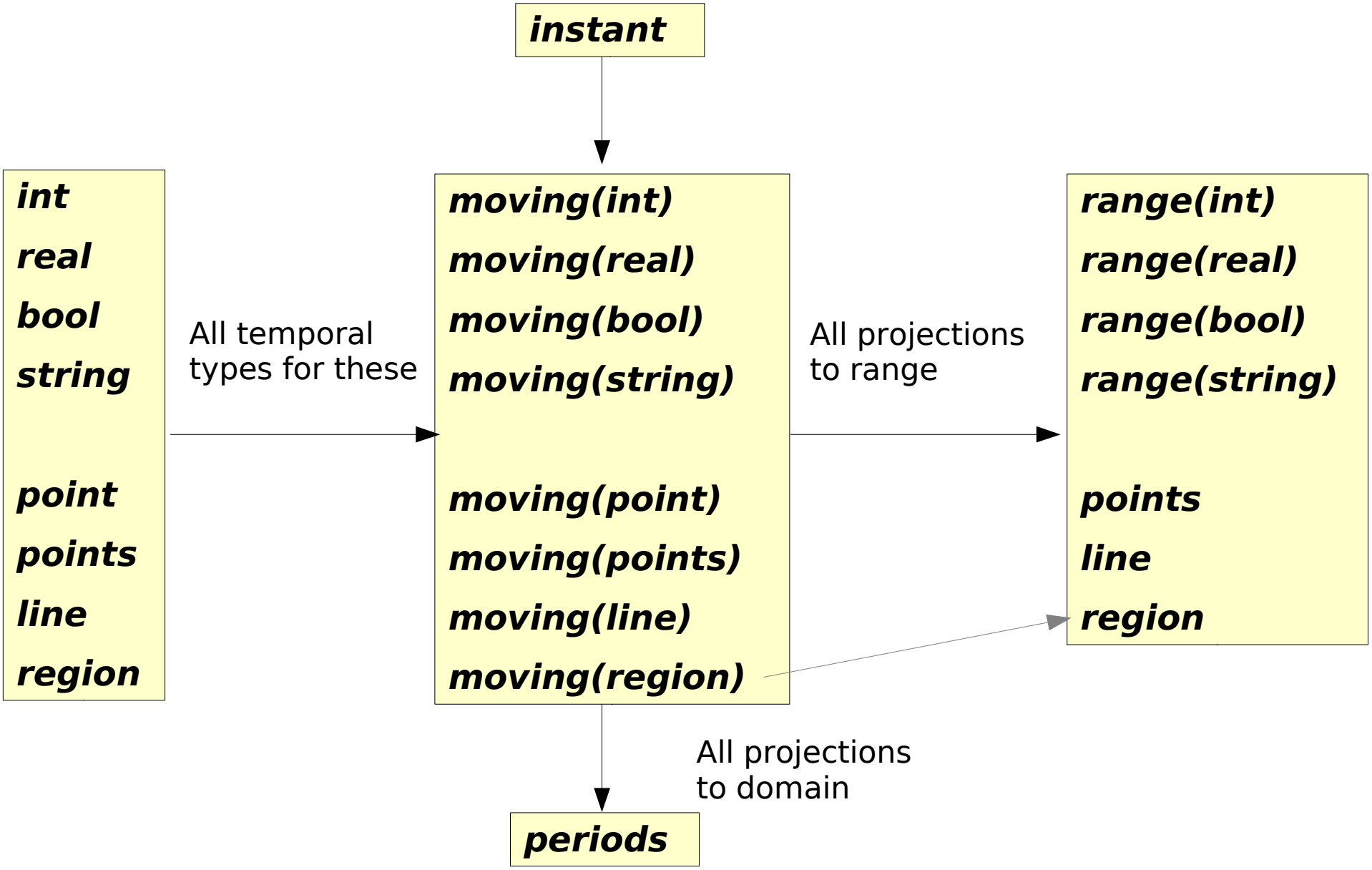
SECONDO: Moving Object Algebra



SECONDO: Moving Object Algebra



SECONDO: Moving Object Algebra



SECONDO: Moving Object Algebra

For each data type α, the set of possible values and its carrier set A_α are:

$$A_{moving(\alpha)} := \{ f \mid f: \overline{A}_{instant} \rightarrow \overline{A}_\alpha \text{ is a partial function}$$
$$\wedge\, \Gamma(f) \text{ is finite} \}$$

$\overline{A}$: carrier set without undefined value.

$\Gamma(f)$: f consists only of a finite number of continuous components.

Each value f is a function describing the development over time of a value from the carrier set A_α.

SECONDO: Moving Object Algebra

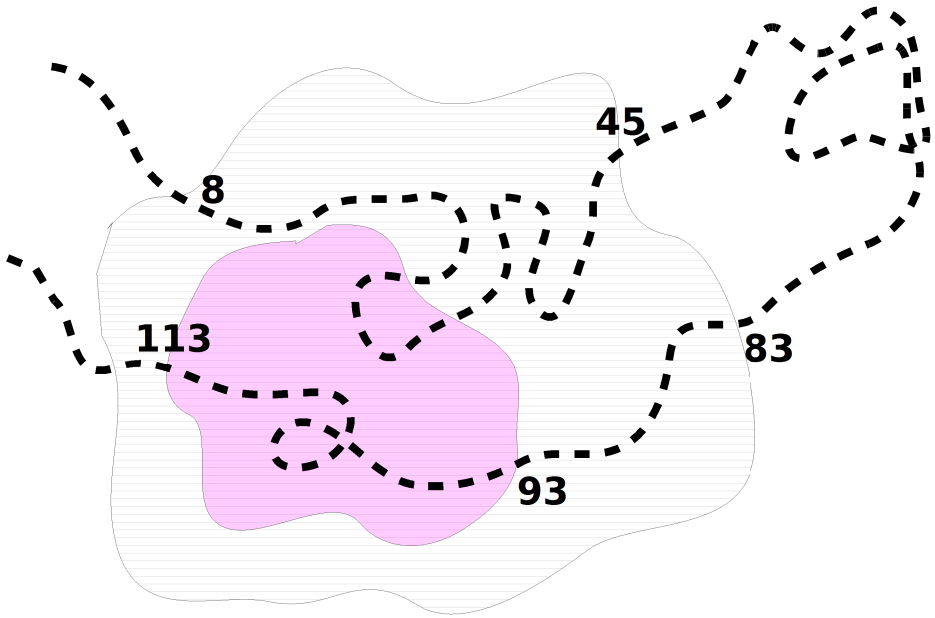
Some Operations

Operation	Signature
trajectory	*moving*(*point*) → *line* *moving*(*points*) → *line*
traversed	*moving*(*line*) → *region* *moving*(*region*) → *region*
intersection	*moving(point)* x *moving(region)* → *moving(point)*
distance	*moving(point) x moving(point)* → *moving(real)*
deftime	*moving(point)* → *periods*
length	*line* → *real*
min	*moving(real)* → *real*

SECONDO: Example of Use

1) Animals a_1 → their locations change continuously over time.

2) Habitat fragmentation area hF_1 → its limit changes continuously over time.




```
habitat_frag (id: string,
    habitat: mregion)

animal_tracking (id: string,
    description: string,
    tracking: mpoint)
```

a_1 from time 1 to 120

hF_1 at time 1

hF_1 at time 50

SECONDO: Example of Use

1) Find all animals that are longer than 5000 km?

```
SELECT *
FROM animal_tracking
WHERE length(trajectory(tracking)) > 5000
```

SECONDO: Example of Use

2) Retrieve any pairs of animals, which, during their tracking, came closer to each other than 500 meters.

```
SELECT *
FROM animal_tracking AS t1, animal_tracking AS t2
WHERE t1.id <> t2.id AND
min(distance(t1.tracking, t2.tracking)) < 0.5
```

SECONDO: Example of Use

3) At what times was animal a1 within the habitat fragmentation area hF1 ?

```
SELECT deftime(intersection(a.tracking, h.habitat))
FROM animal_tracking AS a, habitat_frag AS h
WHERE a.id = 'a1' AND h.id = 'hF1'
```

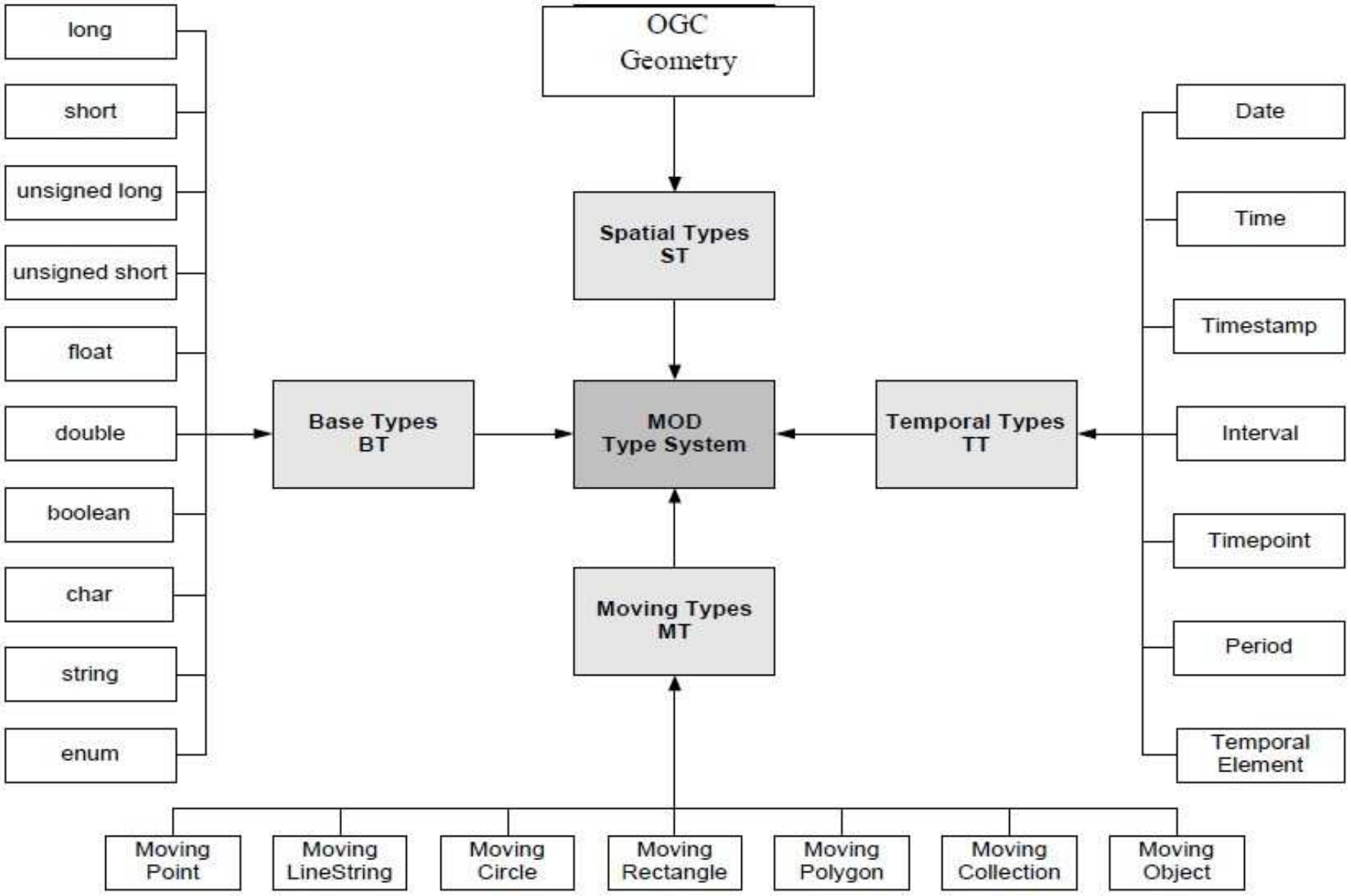
HERMES

- A framework that extends a OGC-compliant ORDBMS by supporting moving object data. [Pelekis, N. et. al, 2010]

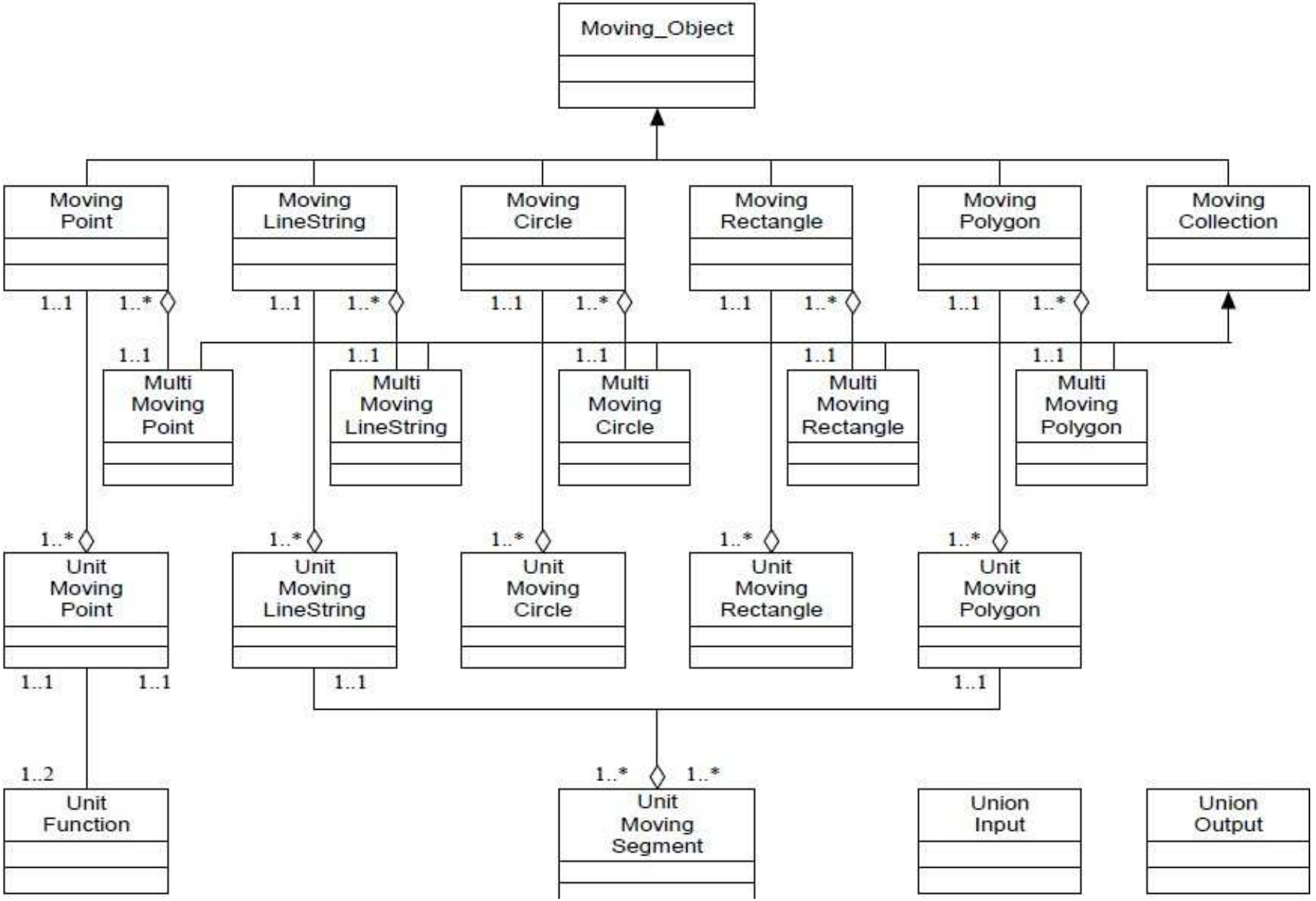
- Moving Object Data: time-varying geometries that change their position and/or extent in space and time dimensions, either discretely or continuously.

- **HERMES MOD** (Moving Object Database) **Engine**: datatype-oriented model and an extension of SQL-like query language for supporting the modeling and querying of moving object database (MOD) on top of OGC-compliant ORDBMS.

HERMES – Data Type Model

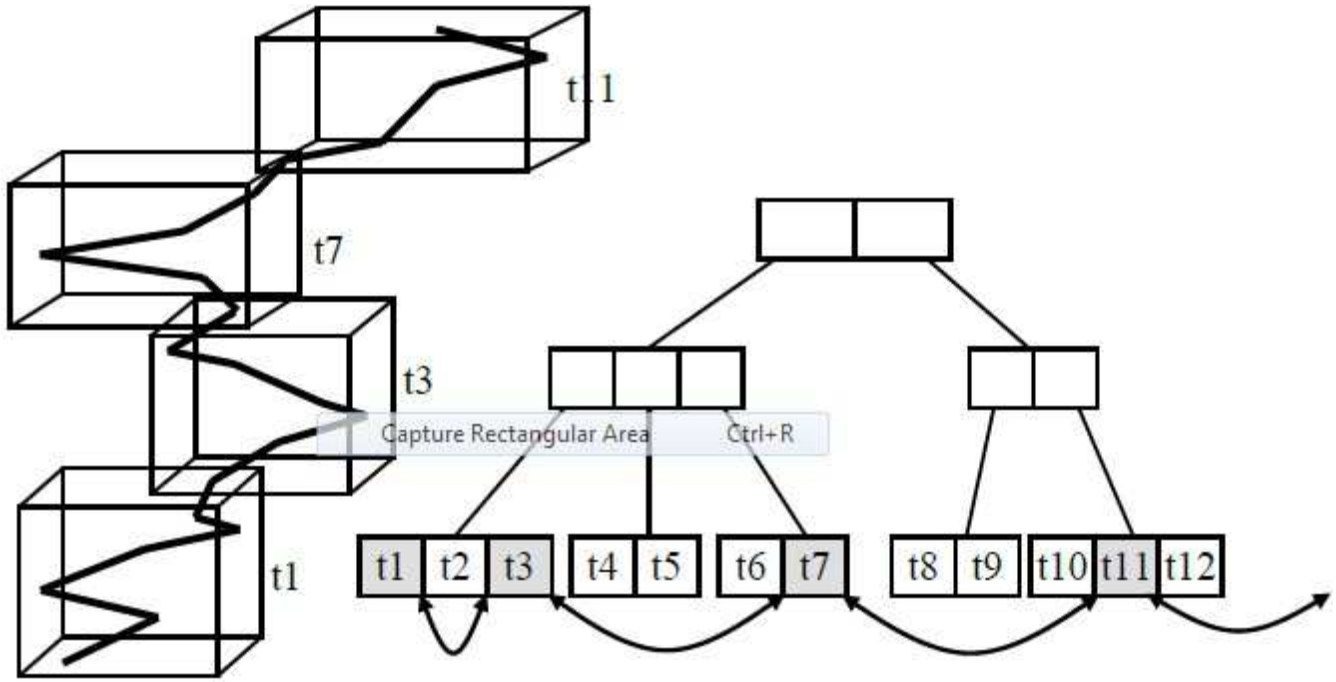


HERMES – Moving Types



HERMES

- It provides:
  - Trajectory Bundle tree (TB-tree)
  - trajectory-based operations
  - k nearest neighbor (k-NN) search
  - different techniques for trajectory similarity search



HERMES

- Proof of concept: it was implemented on top of a commercial ORDBMS, namely **Oracle**, while our design has also been successfully applied and repeated in the open-source **PostgreSQL** / **PostGIS** spatial extension.

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An Observation-Based Spatiotemporal Data Model

Karine Reis Ferreira

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August 2012

Objective

Define a data model to represent and query spatiotemporal data:

(1) Define a set of abstract data types: *data types* and *operations* over them [Guttag, 1978];

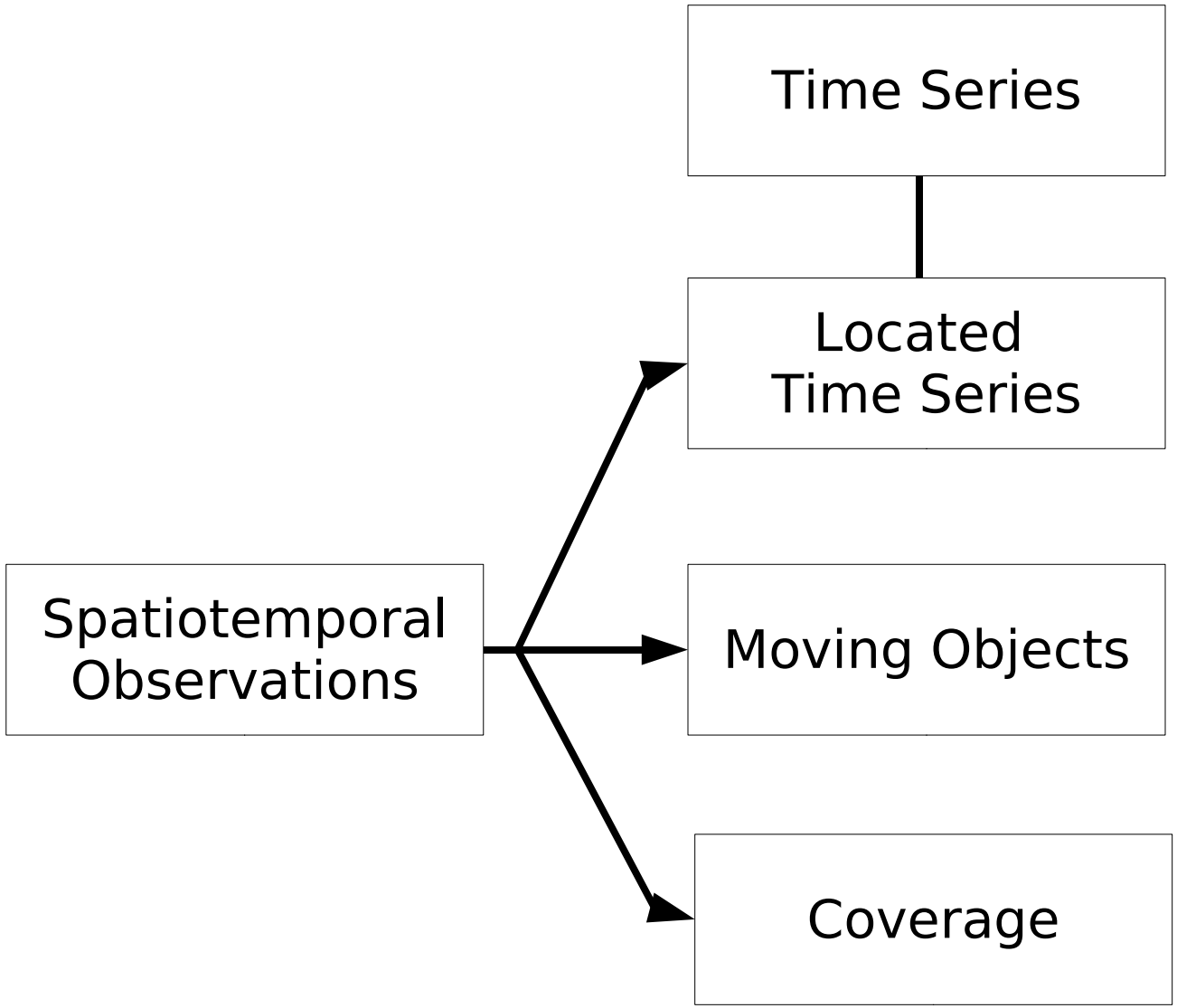
(2) Describe the model by using *algebraic specifications*;

(3) Represent *objects* as well as *fields* which are varying/changing/evolving over time;

The Central Idea

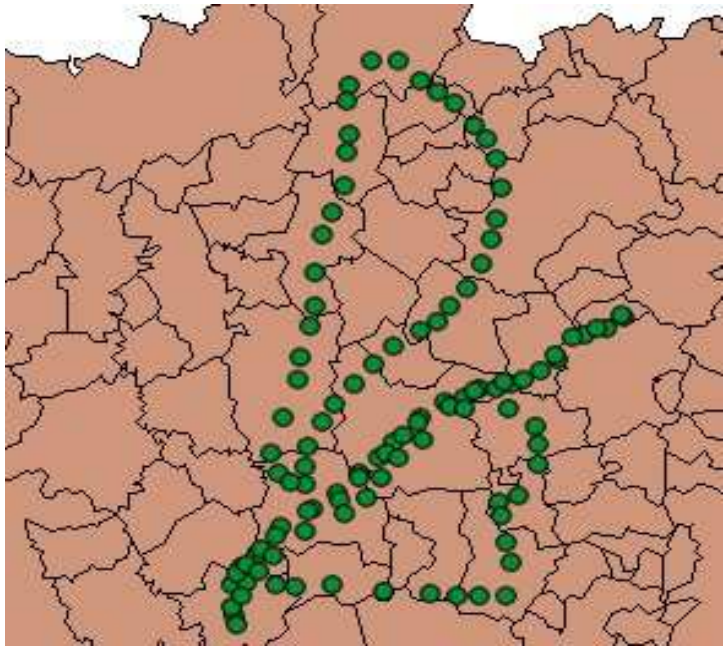
Spatiotemporal Observations: atomic and basic units to represent spatiotemporal data.

An Observation-Based Spatiotemporal Data Model



Why “Observation-Based”

(1) Although most spatiotemporal phenomena are continuous over time and space, they are often measured through discrete observations....

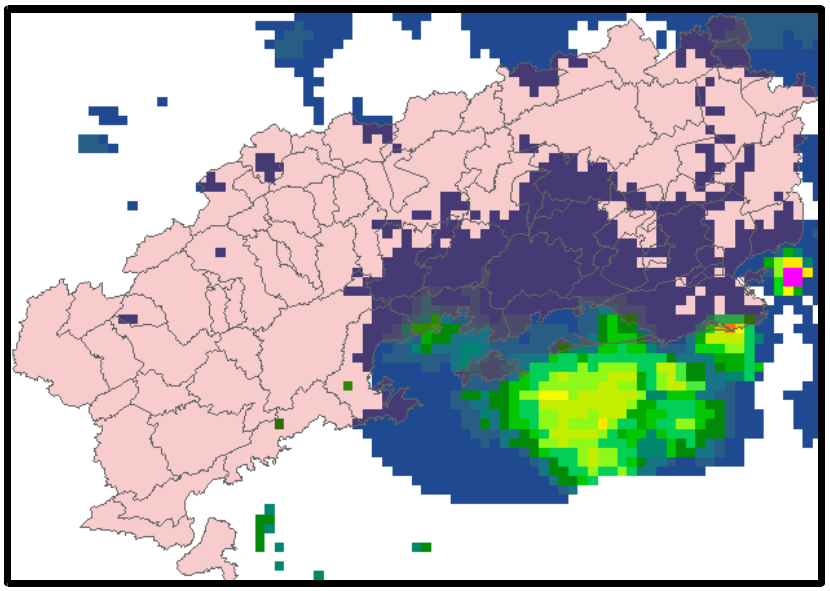


Observations of a moving object.

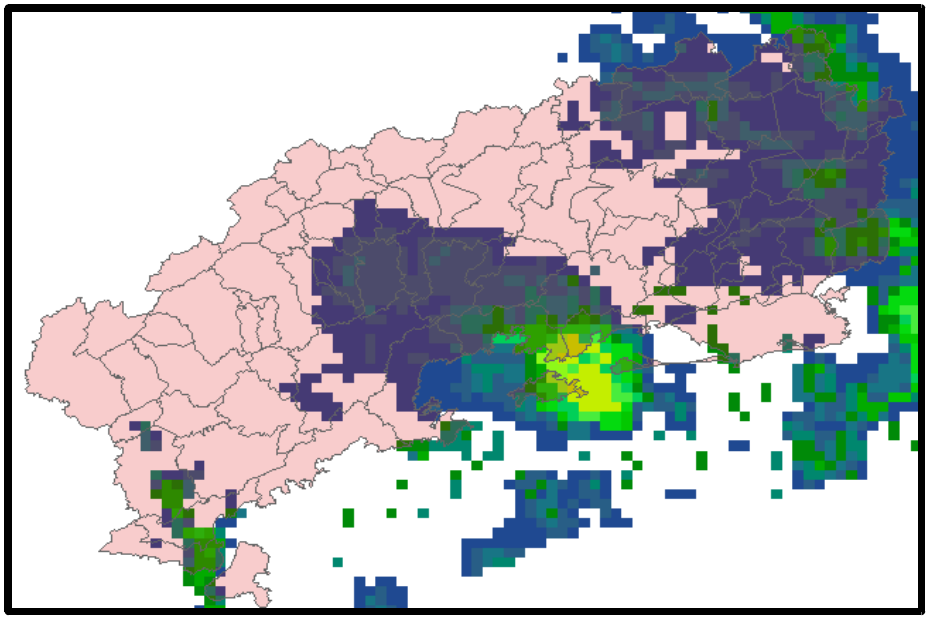
Observations collected in a river in Amazon.

Why “Observation-Based”

(1) Although most spatiotemporal phenomena are continuous over time and space, they are often measured through discrete observations....

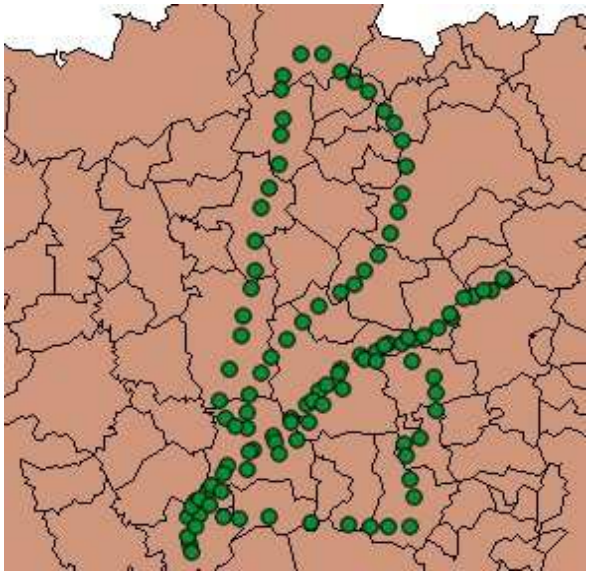


Observations of precipitation.



Why “Observation-Based”

(2) The same set of spatiotemporal observations can be viewed from different perspectives.



Cars moving around a city measuring air pollution information.

→ Spatiotemporal Observations

Each moving car has a coupled sensor that measures, at each 30 minutes, its spatial location and the air pollution in this location.

Why “Observation-Based”

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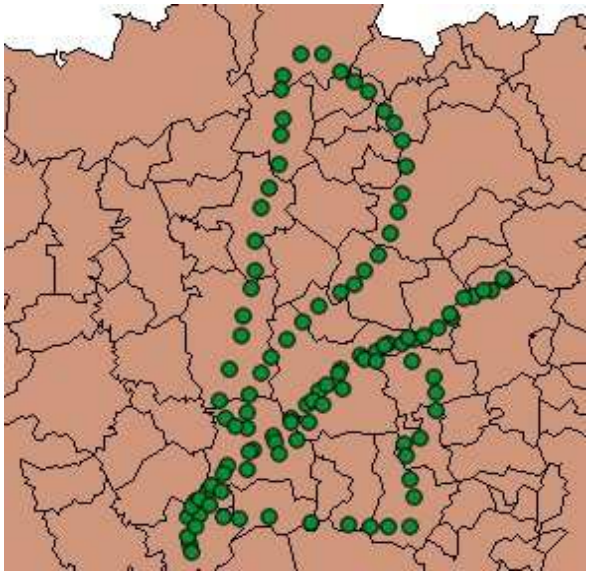


Cars moving around a city measuring air pollution information.

Spatiotemporal Observations

Each moving car has a coupled sensor that measures, at each 30 minutes, its spatial location and the air pollution in this location.

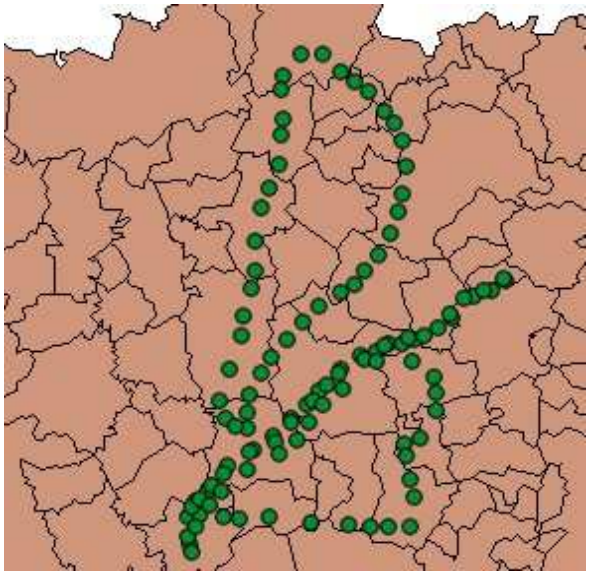
Moving Objects

how the cars move over time and space:

When was the car c_{01} *in the south region of the city and how many hours did it stay there?*”

Why “Observation-Based”

(2) The same set of spatiotemporal observations can be viewed from different perspectives.



Cars moving around a city measuring air pollution information.

→ Spatiotemporal Observations →

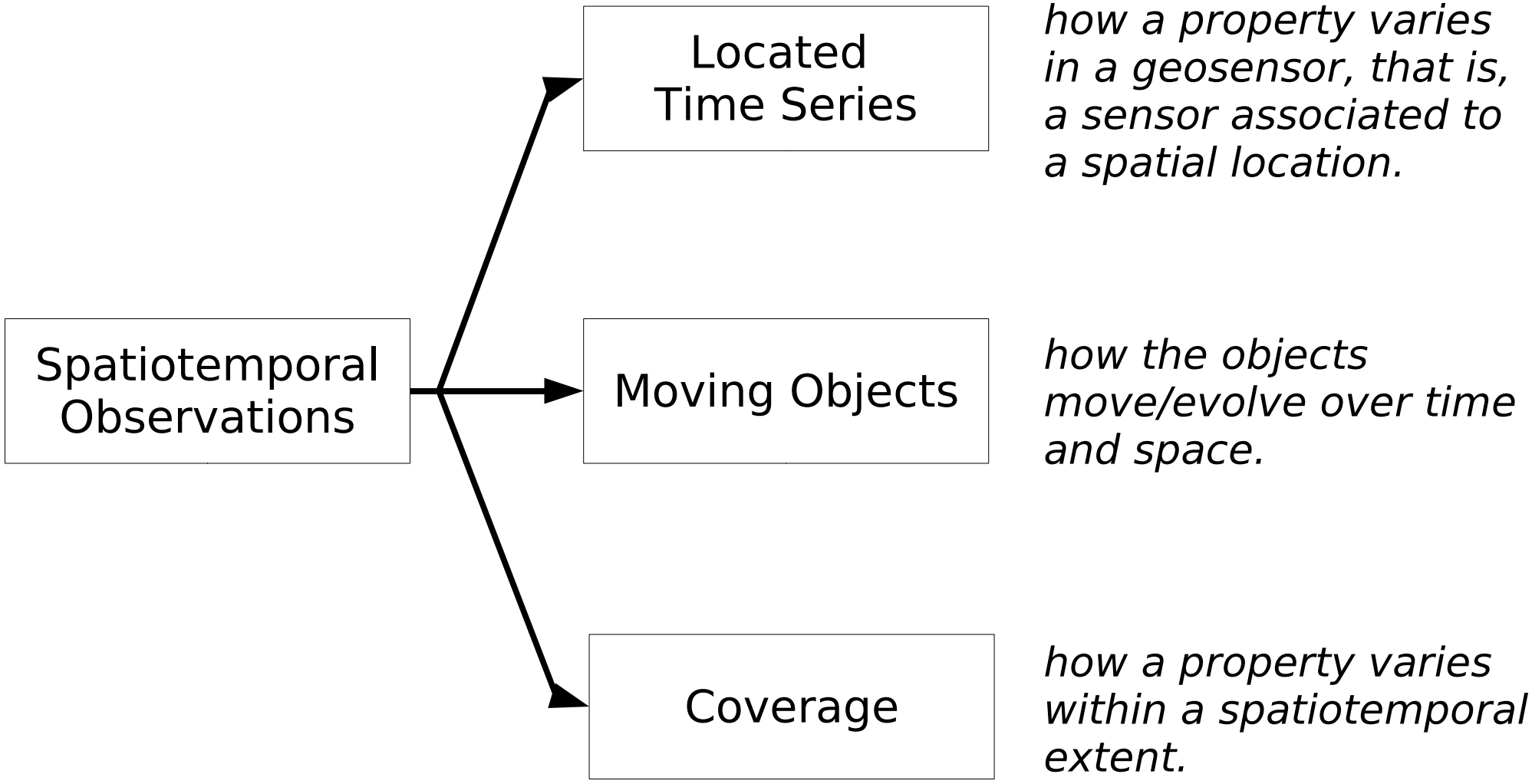
Each moving car has a coupled sensor that measures, at each 30 minutes, its spatial location and the air pollution in this location.

Coverage

how the pollution varies over time along the city regions:

“What city region had the worst pollution index during this week?”

An Observation-Based Spatiotemporal Data Model

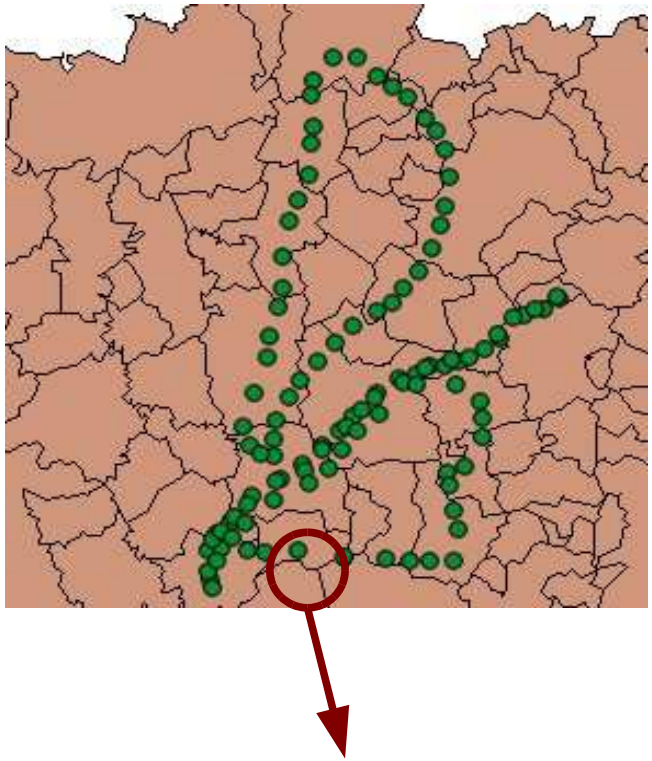


Spatiotemporal Observations

An *observation* is the result of a measurement associated to a discrete time instant or period which assigns values to a phenomenon. [OGC, 2010]

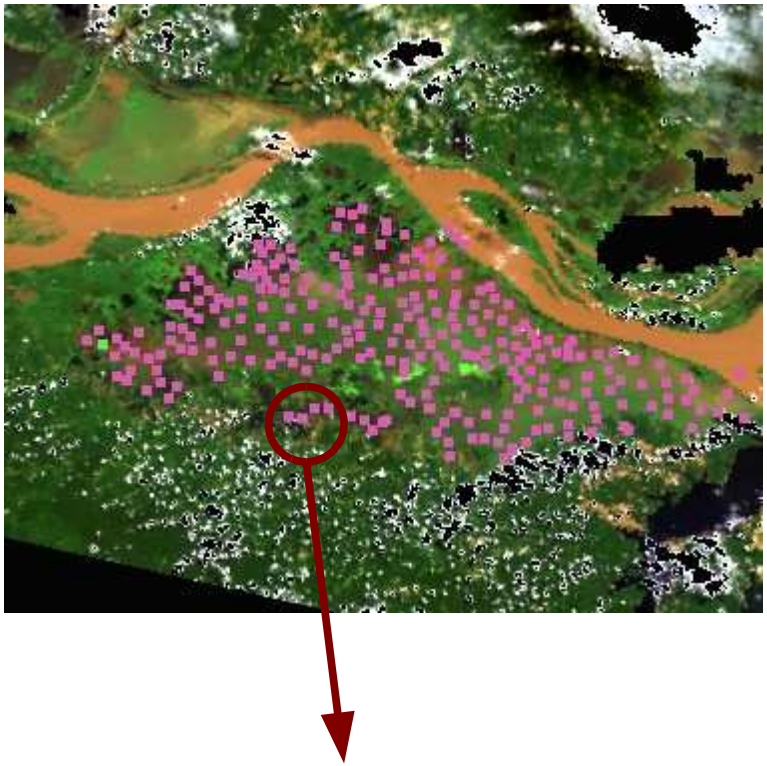
A *spatiotemporal observation* is an observation whose one of its values represents a spatial location or extent.

Spatiotemporal Observations - Examples



Observation of a moving object.

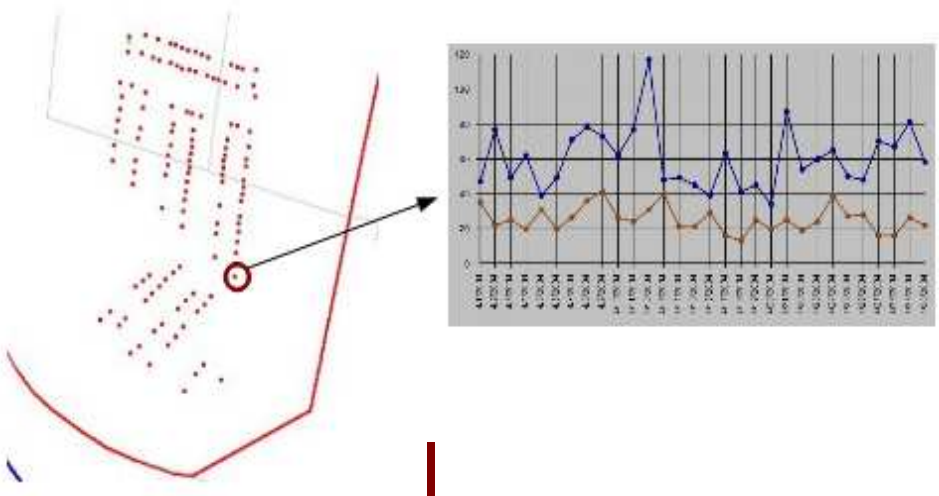
(Instant, Point, Real)



Observation collected in a river in Amazon.

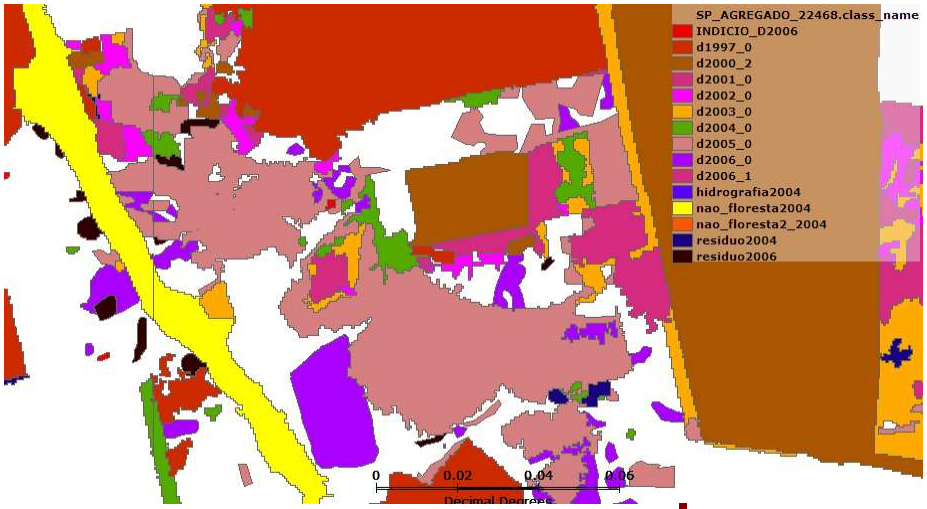
(Instant, Point, Real)

Spatiotemporal Observations - Examples



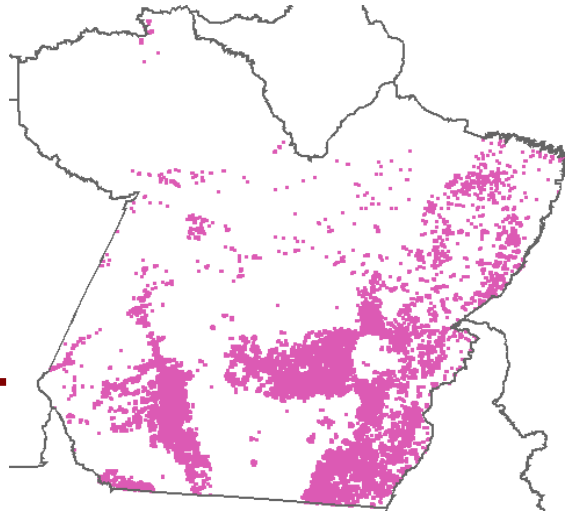
Observations of mosquito eggs.

(Instant, Point, Integer)



Deforested areas.

(Instant, Polygon)



Fire spots

(Instant, Point)

Time Series and Located Time Series

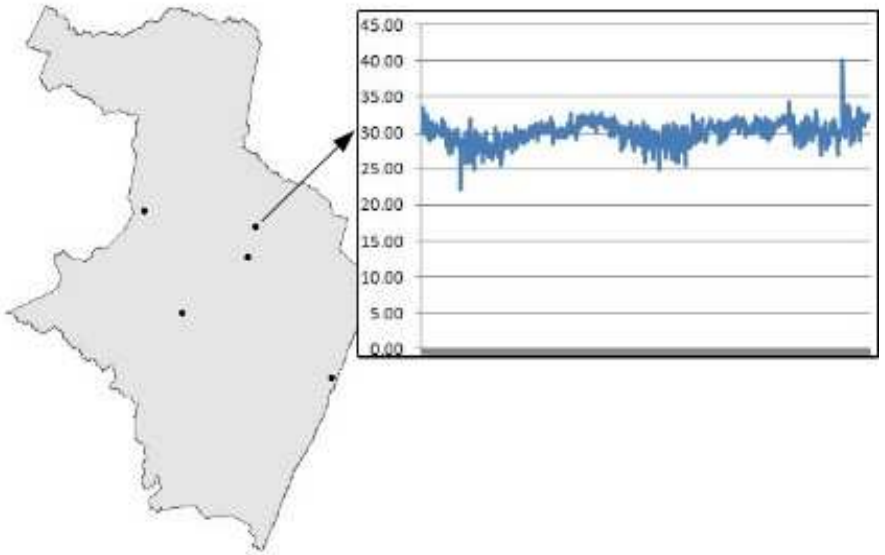
Time Series

Located Time Series

Spatiotemporal Observations

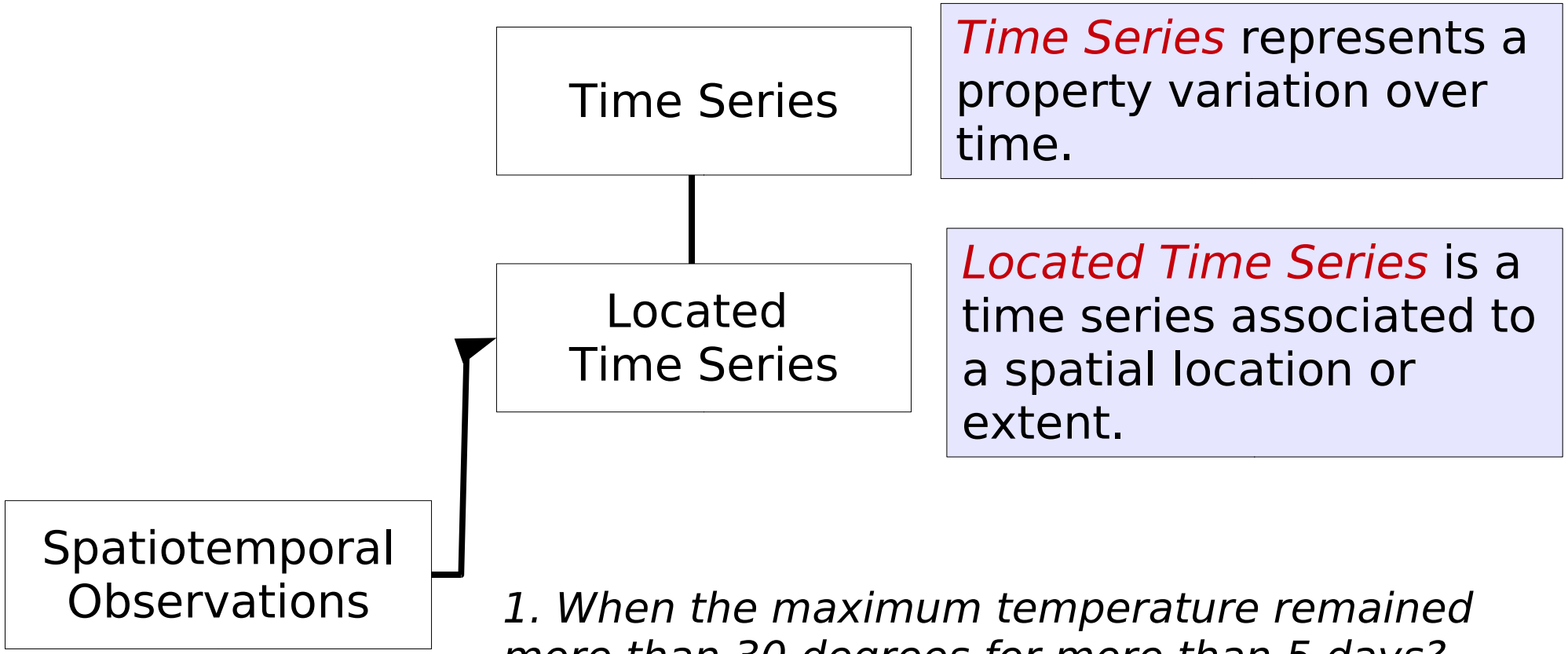
Time Series represents a property variation over time.

Located Time Series is a time series associated to a spatial location or extent.



(a)

Time Series and Located Time Series



1. When the maximum temperature remained more than 30 degrees for more than 5 days?

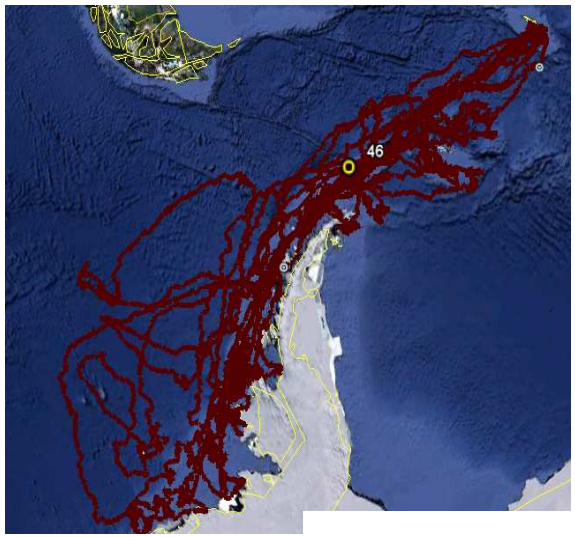
2. When an abrupt temperature changes happened (when abrupt temperature change means that the different between the maximum temperature in a period of 24 hours is more than 10 degrees)?

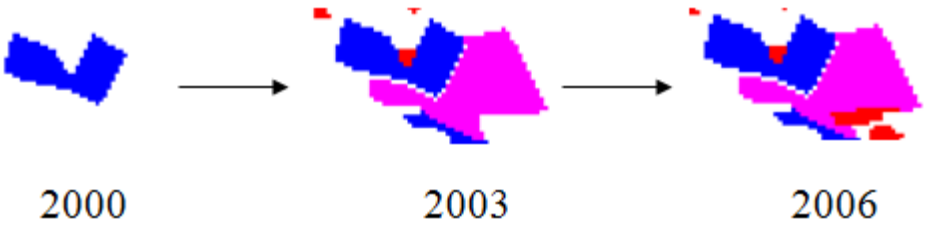
Moving Objects

Moving Object

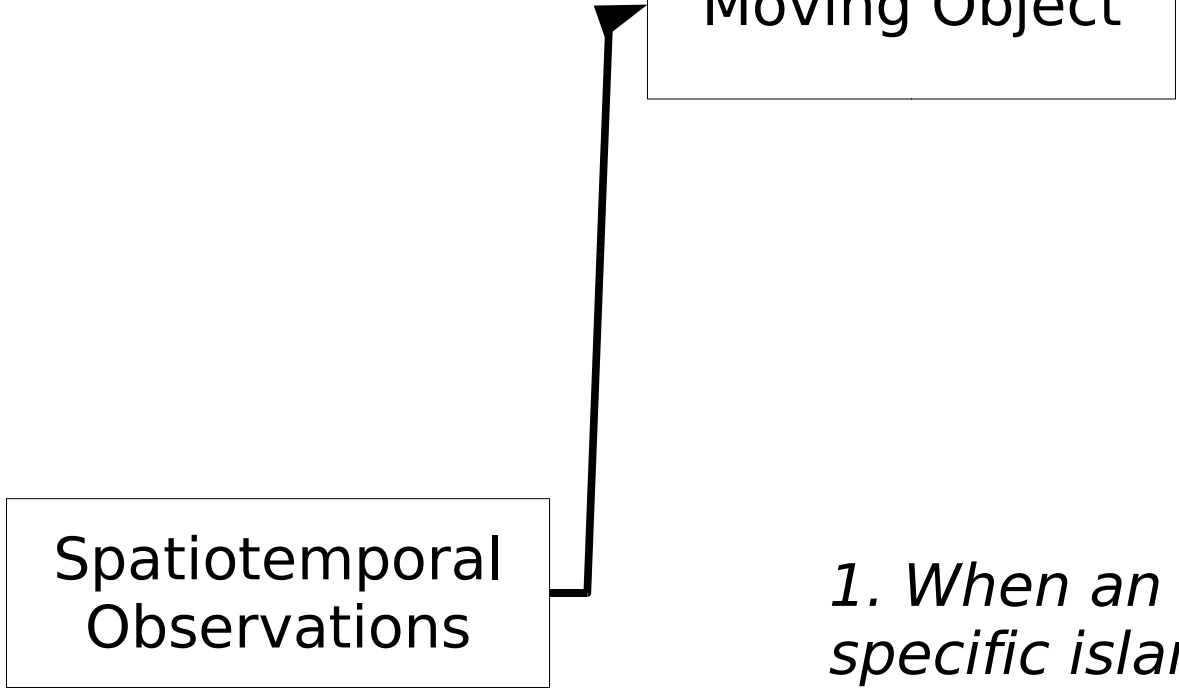
Spatiotemporal Observations

Moving objects are entities whose spatial positions or extents change continuously over time [Guting and Schneider, 2005].





Moving Objects



Moving objects are entities whose spatial positions or extents change continuously over time [Guting and Schneider, 2005].

1. When an animal reached a specific island?

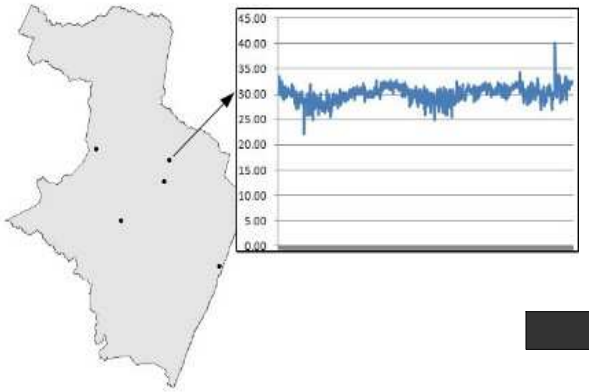
2. Extract daily trajectories of the animals.

Coverage

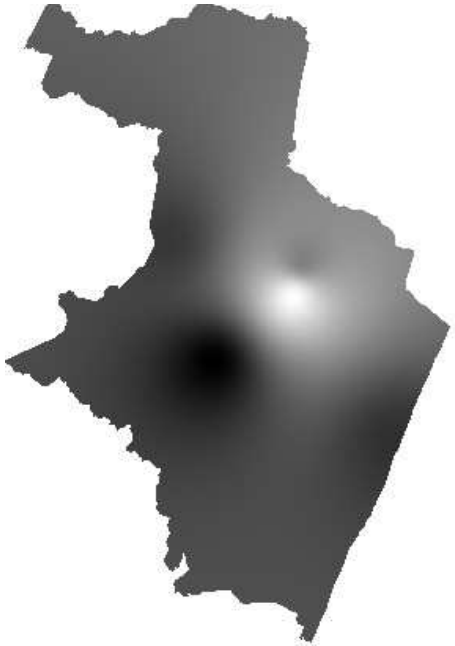
Coverage

A *Coverage* represents a property variation within a spatiotemporal extent.

Spatiotemporal Observations



(a)

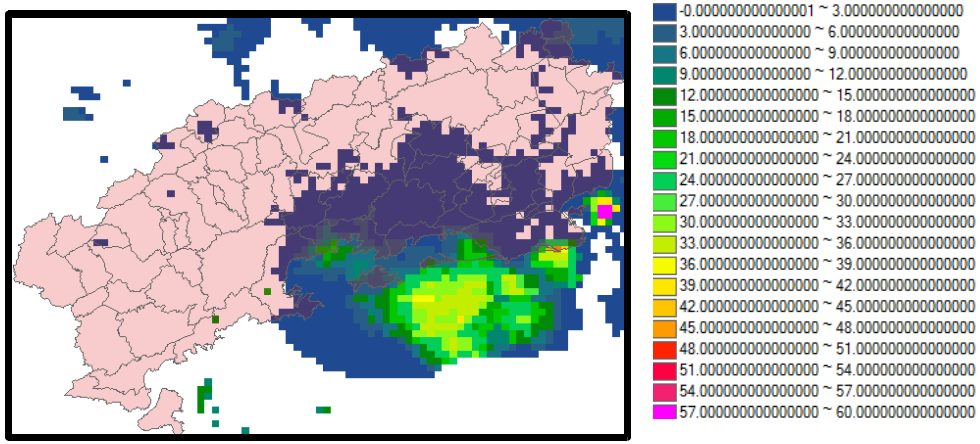


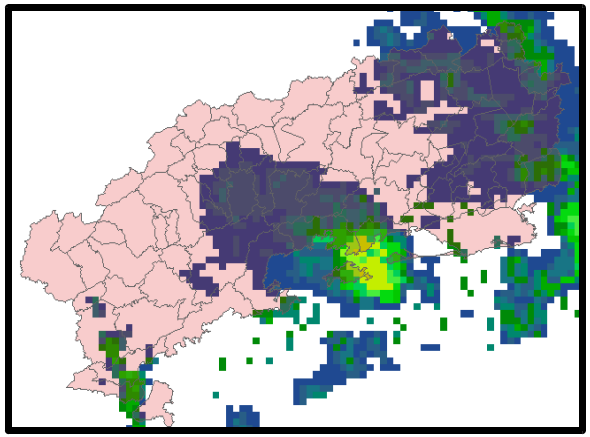
Coverage

Coverage

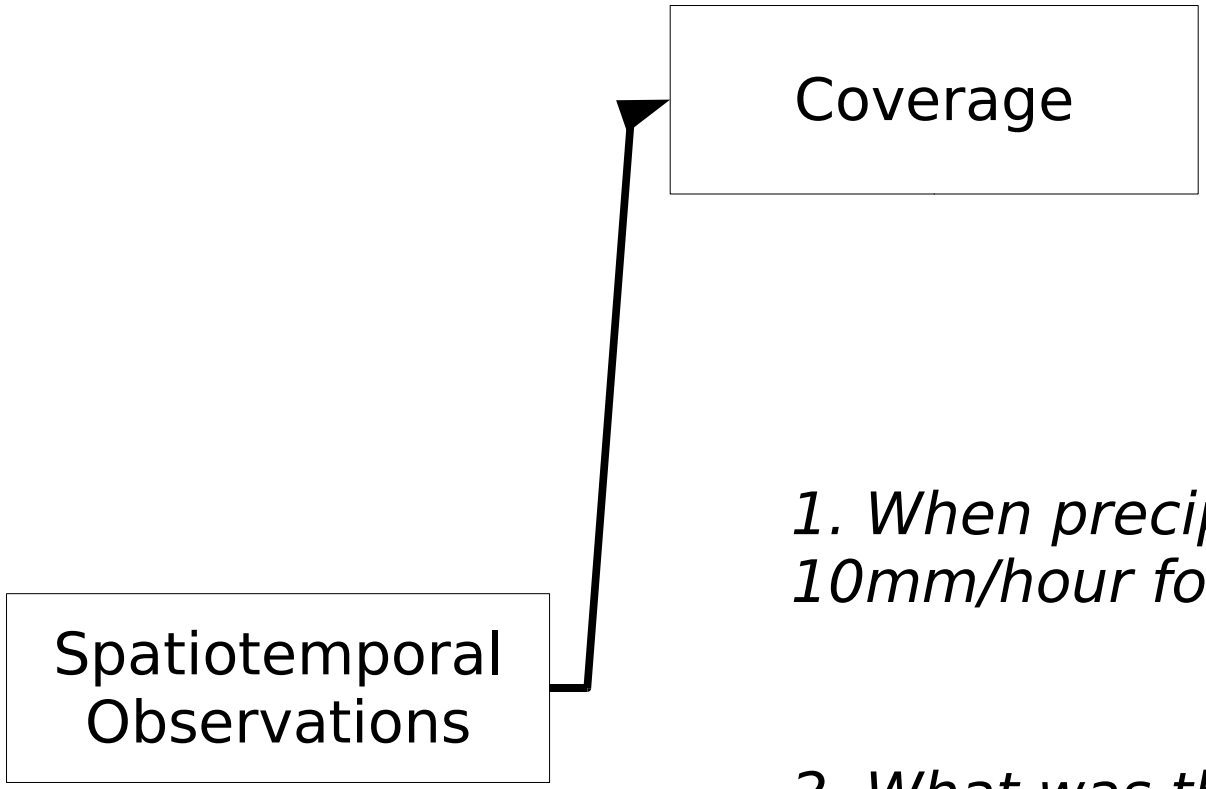
Spatiotemporal Observations

A *Coverage* represents a property variation within a spatiotemporal extent.





Coverage



A *Coverage* represents a property variation within a spatiotemporal extent.

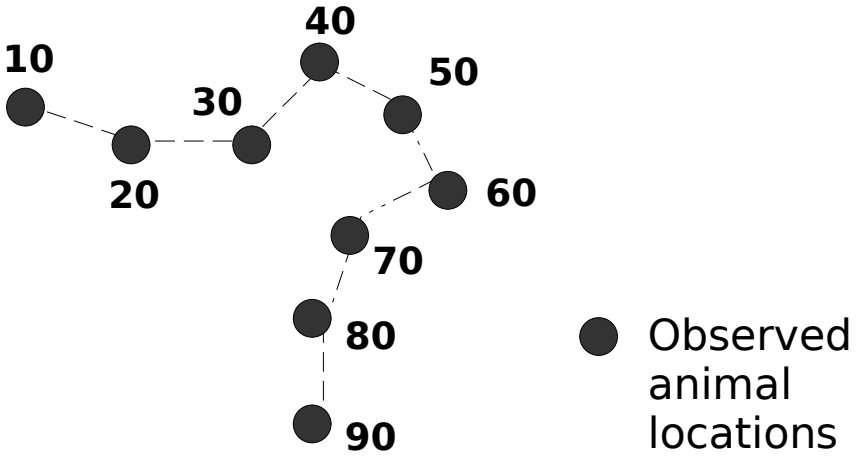
1. When precipitation was > 10mm/hour for 5 hours in Angra city?

2. What was the variation of the precipitation over time in the point P?

Interpolation Function

Data Types: Set of Observations + Interpolation Function

Definition: An *interpolation function* is a procedure that, given a set of discrete observations and some specific parameters, is able to estimate a value in any non-observed position in time, in space or in space and time.

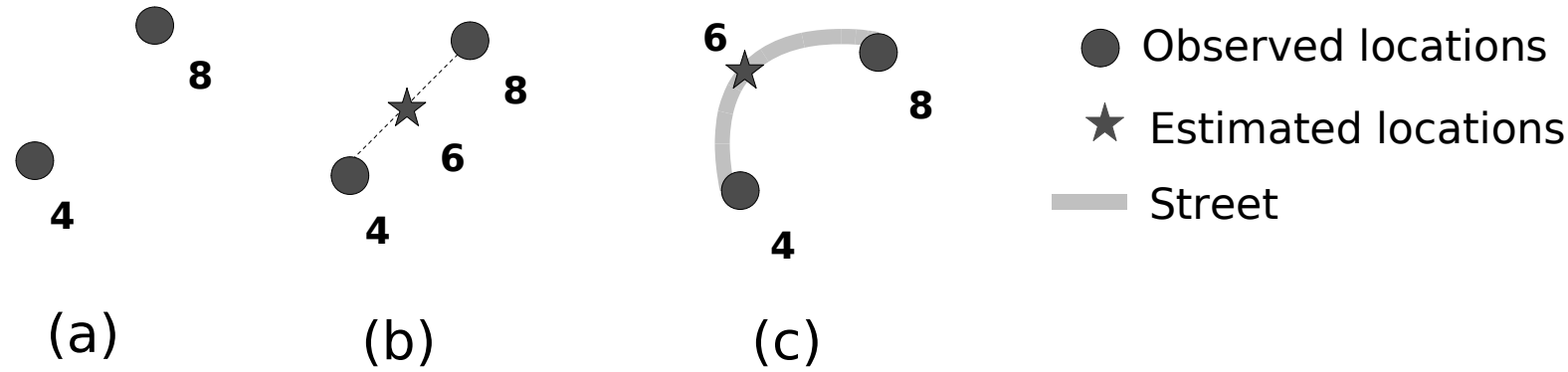


Moving Object

Coverage

Interpolation Function - Examples

Different kinds of interpolators can be defined and used over the same set of observations.



(a) given two car locations, one observed at time instant 4 and another at 8

(b) linear interpolator to estimate the non-observed time 6

(c) interpolator which regards a street map in its estimation

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Moving Objects and Trajectories

Karine Reis Ferreira

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August 2012

Objetivo

(1) Estudo/Pesquisa sobre representação, consultas/operações e visualização de **objetos móveis** e **trajetórias**.

(2) Implementação de um módulo de software na TerraLib5 para tratar **objetos móveis** e **trajetórias**.

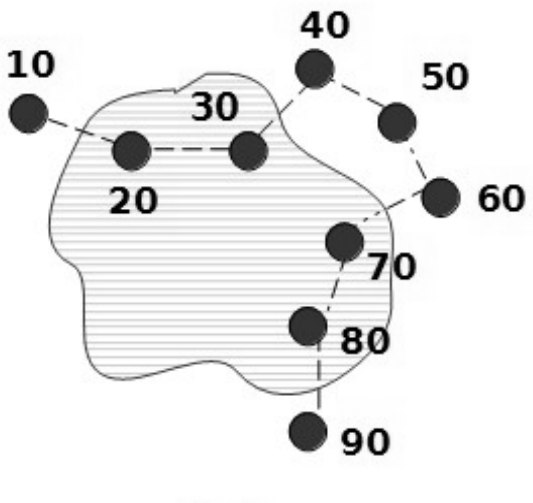
Moving Objects - Conceito

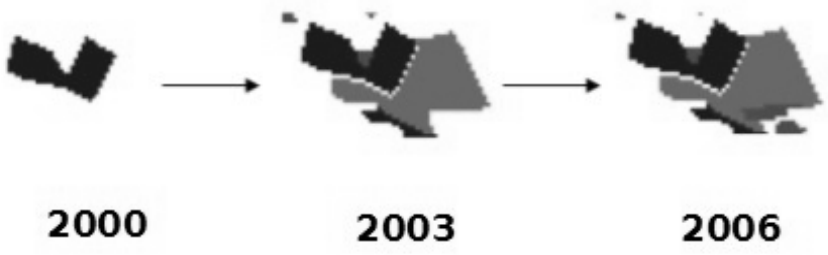
Moving Objects é um conceito já bem estabelecido e conhecido em “GIS science”.

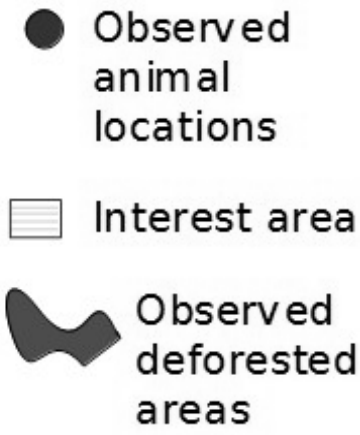
Moving Objects are entities whose spatial positions or extents change continuously over time (Guting and Schneider, 2005).

Moving Objects - Exemplos

Moving Objects are entities whose spatial positions or extents change continuously over time (Guting and Schneider, 2005).







Animal tracking

↓

moving point

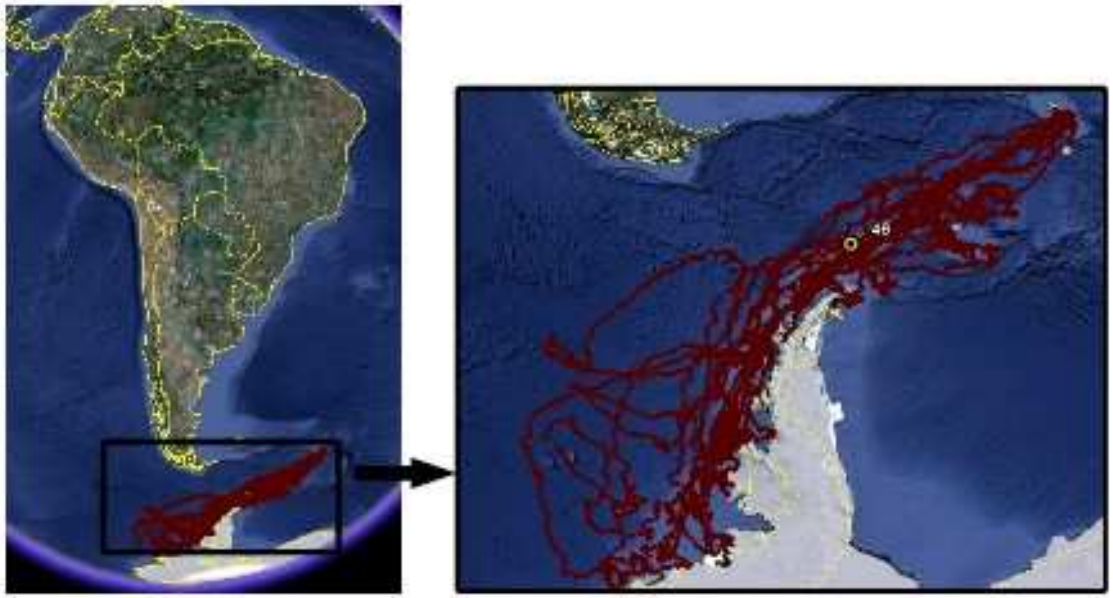
Deforested region evolution

↓

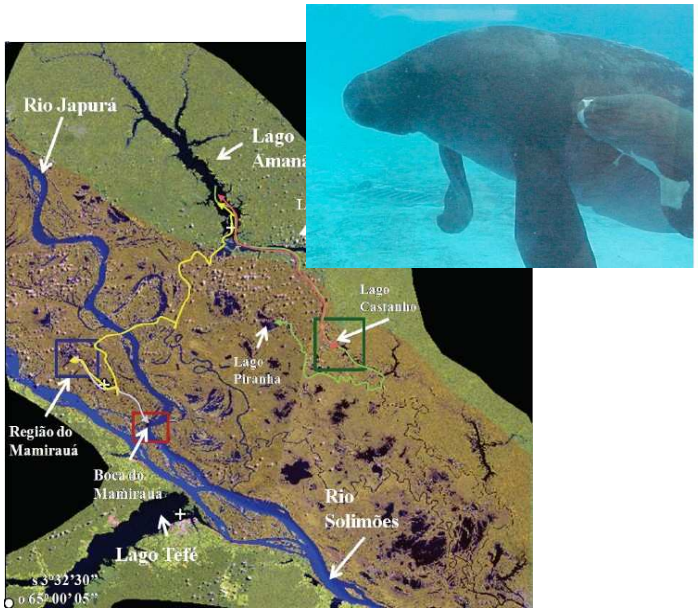
moving region

Moving Objects - Exemplos

Moving Objects are entities whose spatial positions or extents change continuously over time (Guting and Schneider, 2005).



A project that monitors sea elephants in the Antarctica.



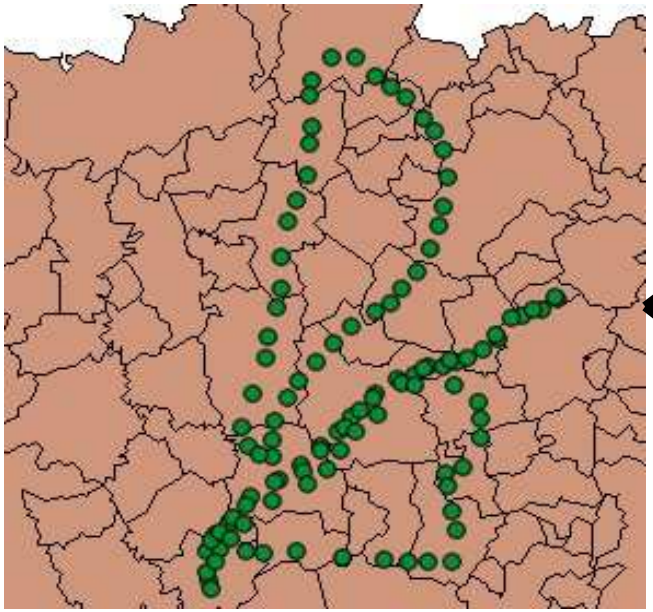
(Arraut, E. M. 2008)

Trajectory - Conceito

Trajectories are countable journeys associated to objects which are moving in space over time. (Spaccapietra et. al, 2008).

Trajectory - Exemplos

Trajectories are countable journeys associated to objects which are moving in space over time. (Spaccapietra et. al, 2008).



Quais as trajetórias diárias do carro X_1?

Quais as trajetórias do carro X_1 na zona sul da cidade?

Quais as trajetórias do carro X_1 com velocidade maior que 60 km/h?

Monitoramento de carros em uma ciadade. Cada carro é um *moving object*.

Diferentes trajetórias de um mesmo *moving object*.

Trajectory - Exemplos

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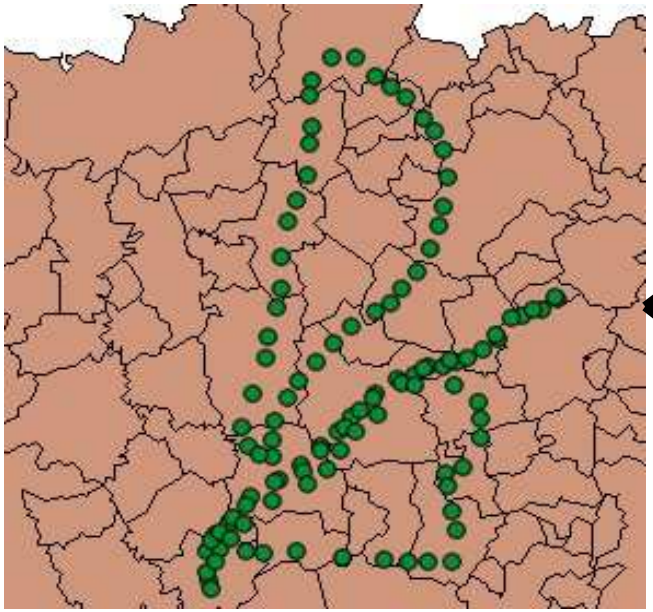

Quais as trajetórias **diárias** do carro X_1?

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Monitoramento de carros em uma ciadade. Cada carro é um *moving object*.

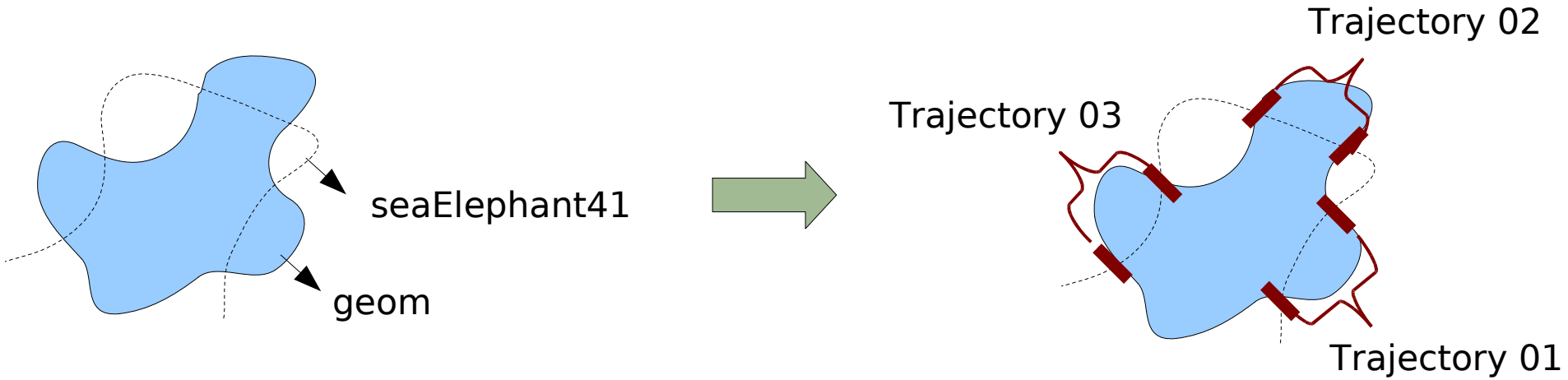
Diferentes trajetórias de um mesmo *moving object*.

Moving Objects – Algumas Operações

intersection: MovingObject x Geometry → {Trajectory}

difference: MovingObject x Geometry → {Trajectory}

intersection(seaElephant41, geom)



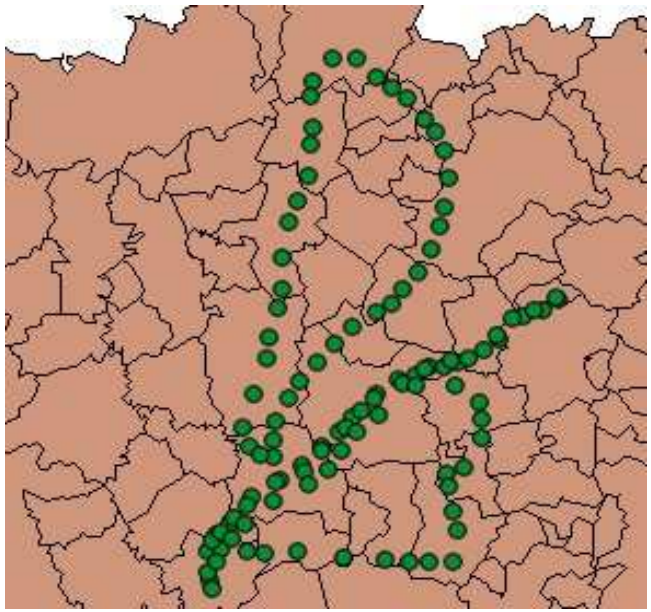
Moving Objects – Algumas Operações

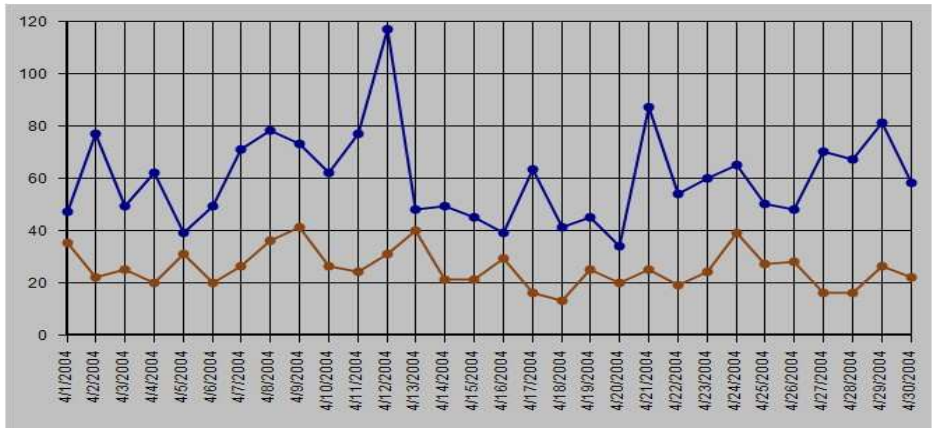
distance: MovingObject x MovingObject → TimeSeries

enters, **exits**, **reaches**, **leaves**:

MovingObject x Geometry → {Trajectory}

distance(car1, car2)





Moving Objects – Algumas Operações

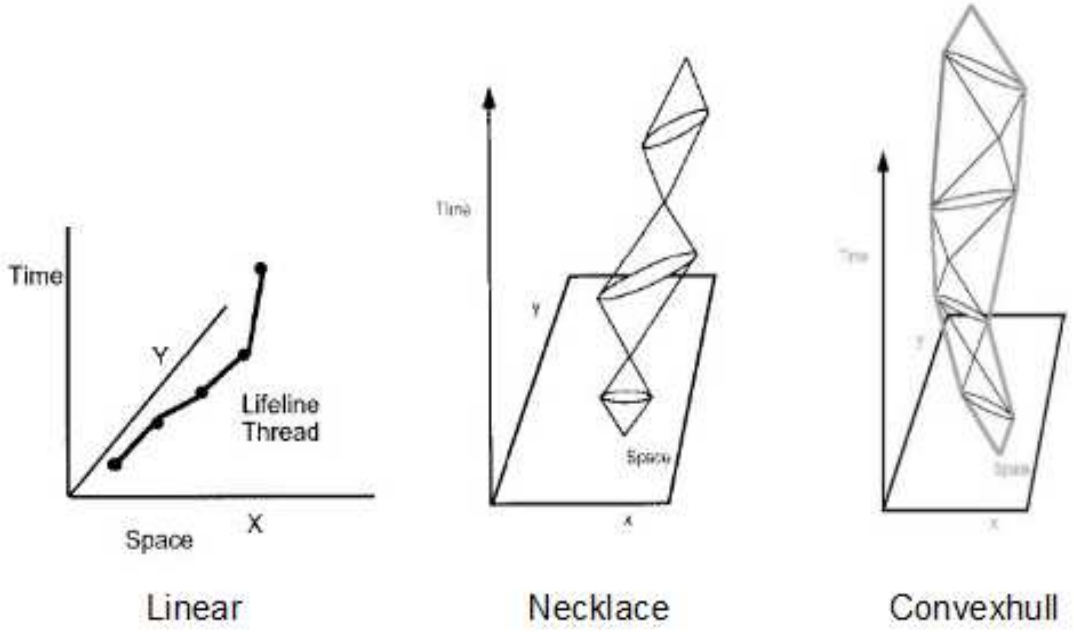
speed: MovingPoint → TimeSeries

direction: MovingPoint → TimeSeries

linearPath: MovingPoint → Line

necklacePath: MovingPoint → MultiPolygon

convexhullPath: MovingPoint → Polygon

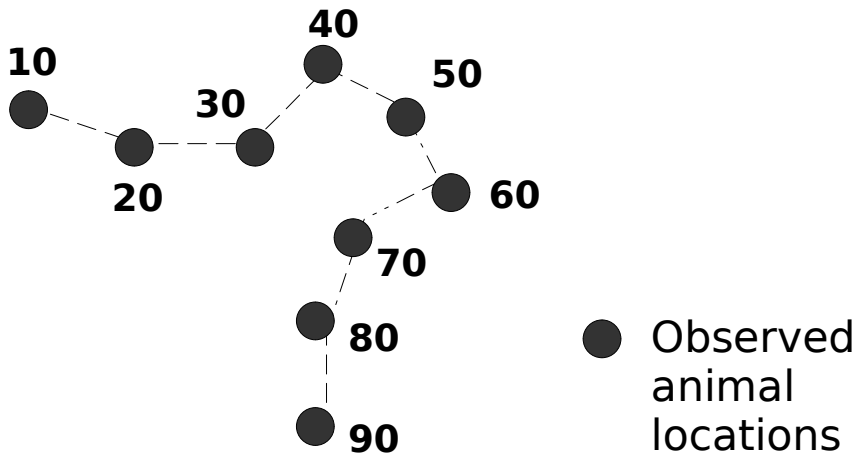


(Hornsby and Egenhofer, 2002)

Interpolation Function

Moving Object: Set of Observations + Interpolation Function

An *interpolation function* (or *interpolators*) for moving objects is a procedure that is able to estimate a spatial position or extent at any non-observed time.

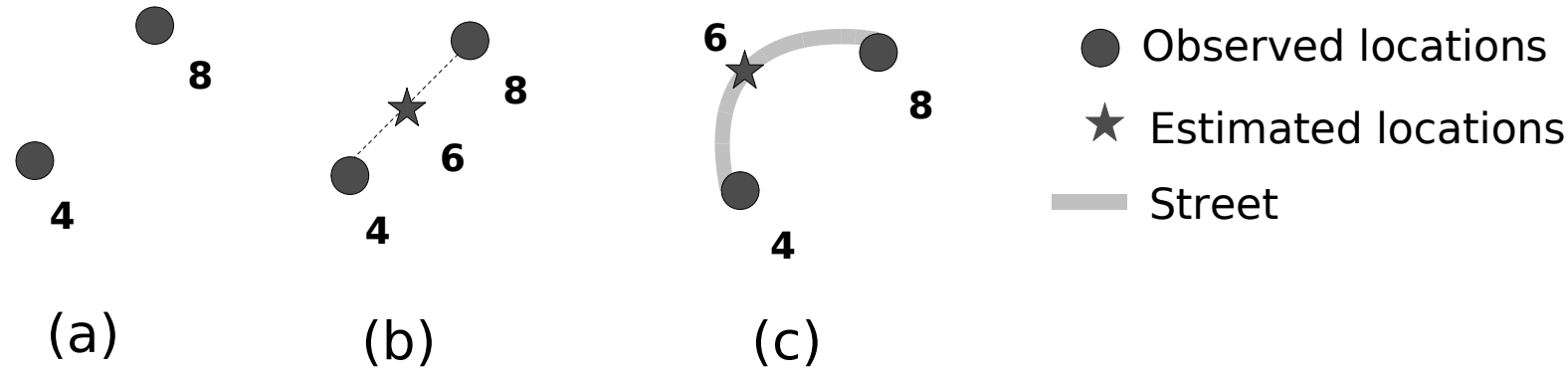


Moving Object

Where was the animal at time 55?

Interpolation Function - Examples

Different kinds of *interpolators* can be defined and used over the same set of observations.



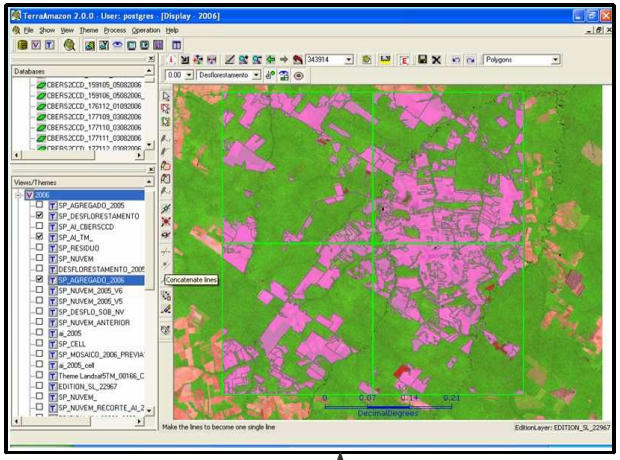
(a) given two car locations, one observed at time instant 4 and another at 8

(b) linear interpolator to estimate the non-observed time 6

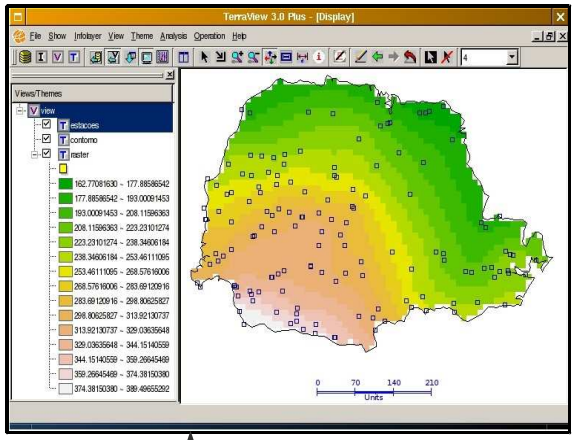
(c) interpolator which regards a street map in its estimation

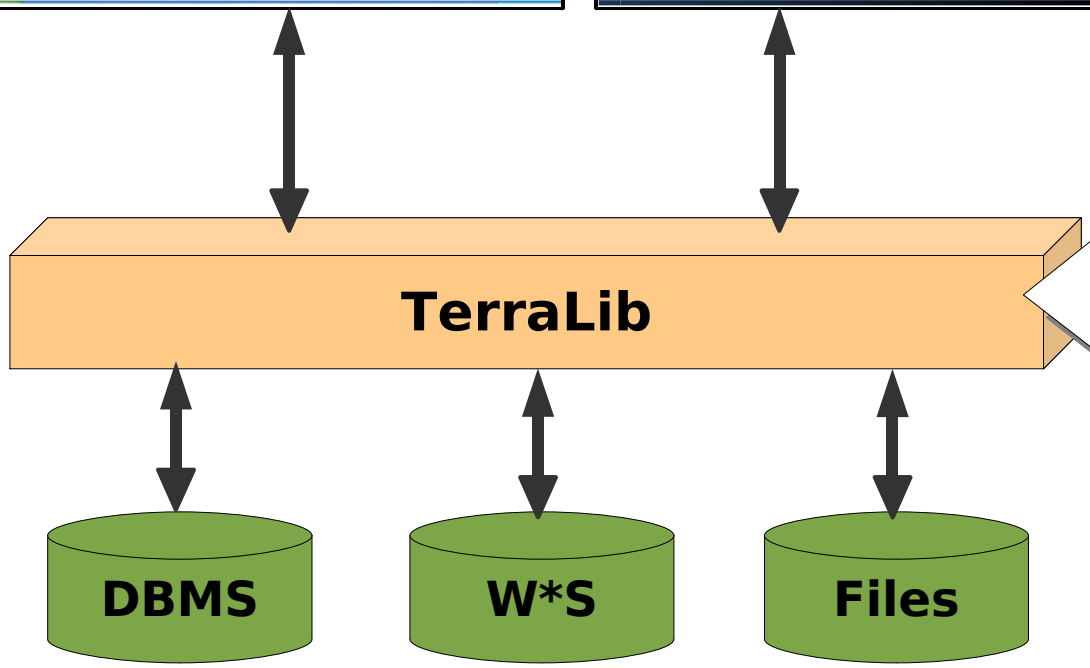
TerraLib: a FOSS geographic library

TerraAmazon



TerraView





Software library base to develop geographic information systems.

Free and Open Source Software (FOSS).

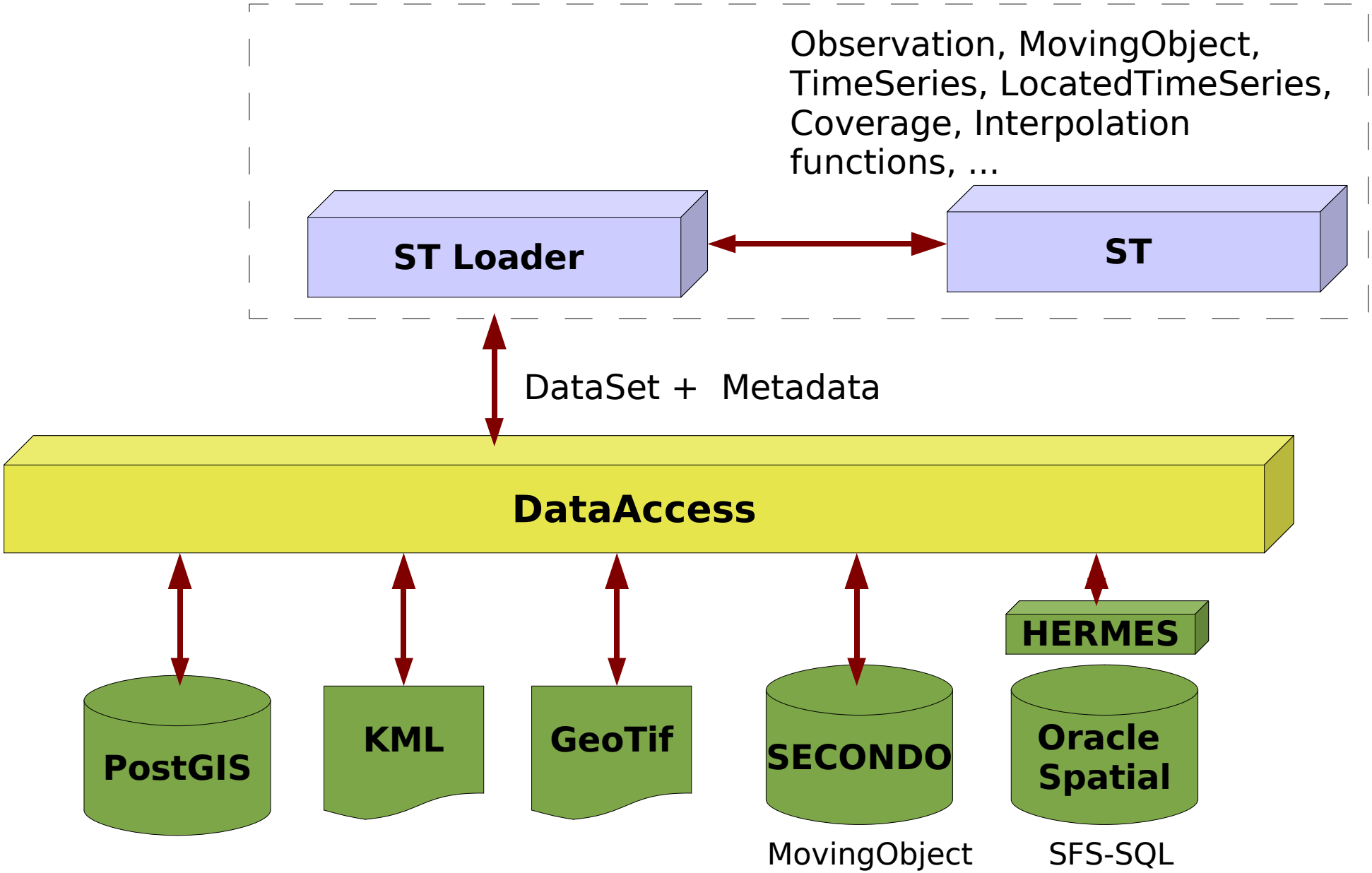
Developed by INPE.

C++ language.

Provides: spatial operations,image processing, spatial analysis, R interface, ...

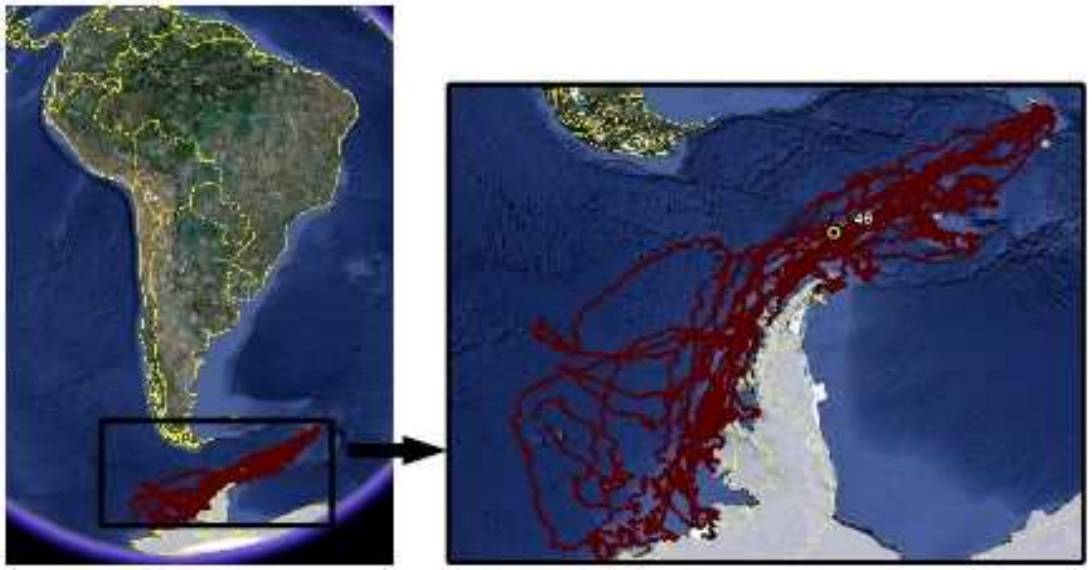
www.terralib.org

TerraLib: Modules for Spatiotemporal data



TerraLib ST Loader Module – An Example

KML file



A project that monitors sea elephants in the Antarctica.

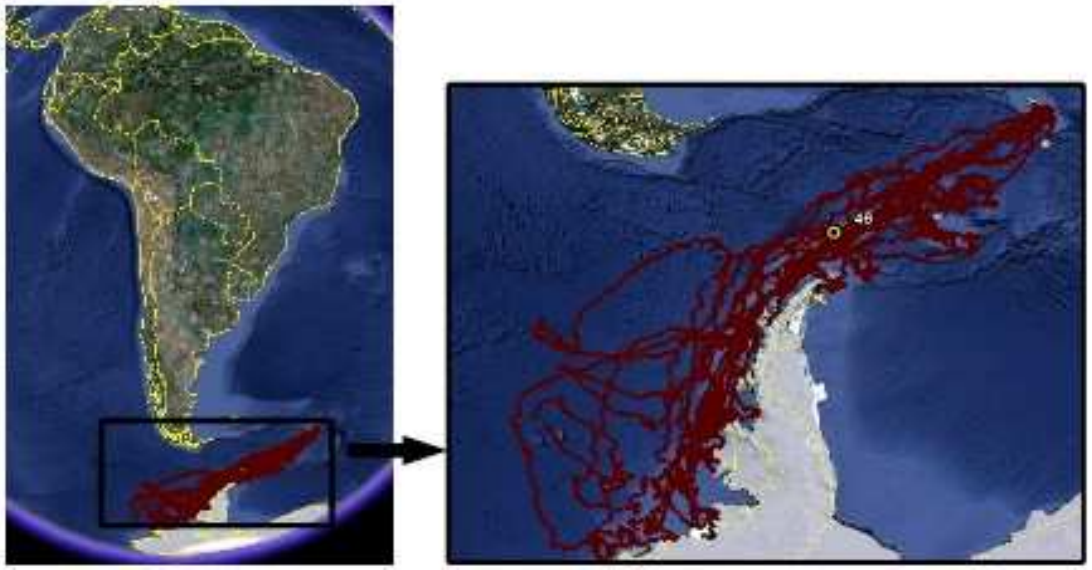
- All observations of each sea elephant: `kml::FolderType`.

- Each animal observation is represented by a `kml::PlacemarkType` type: (a) spatial location: `kml::PointType`; (b) time instant: `kml::TimeStampType`

TerraLib ST Loader Module – An Example

How to extract moving objects from KML files?

KML file



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TerraLib ST Loader Module – An Example

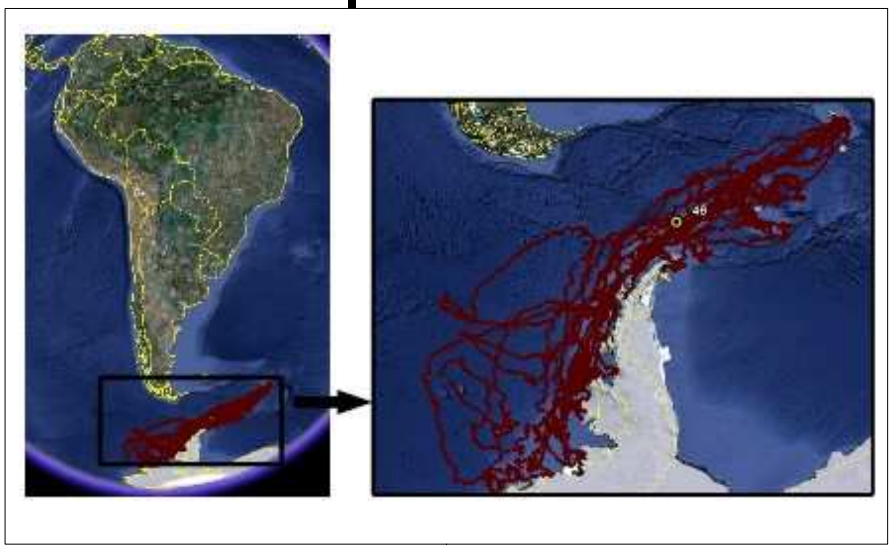
- Although KML files can be used to describe **journeys**, there is not a standard way to represent them as trajectories of moving objects for further analysis;
- Each software or mobile device that generates KML files with journeys uses its own structure for representing them;
- We can visualize journeys described in KML files in many software tools, such as Google Earth, but few of them are able to process or analyze these journeys as moving object trajectories:
  - *“When did object o1 enter a specific region r10 and how long did it stay in this region?”*

TerraLib ST Loader Module – An Example

XML metadata file

ST Loader

KML file



```
<?xml version="1.0" encoding="UTF-8" standalone="no"?>
<MovingObjectMetadata
    xmlns:xlink="http://www.w3.org/1999/xlink"
    xmlns:xsd="http://www.w3.org/2001/XMLSchema-instance"
    xmlns="http://www.terralib.org/movingobjectmetadata"
    xsd:schemaLocation=
    "http://www.terralib.org/movingobjectmetadata
                                movingobjectmetadata.xsd">
<kmlFileName>sea_elephants</kmlFileName>
<MovingObject>
    <name>2340</name>
    <type>MovingPoint</type>
    <ObservationContainer>
        <type>kml::FolderType</type>
        <name>40: locations</name>
    </ObservationContainer>
</MovingObject>
<MovingObject>
    <name>2341</name>
    <type>MovingPoint</type>
    <ObservationContainer>
        <type>kml::FolderType</type>
        <name>41: locations<name>
    </ObservationContainer>
</MovingObject>
</MovingObjectMetadata>
```

TerraLib: Code example

```
DataSource* ds = DataSourceFactory::make("OGR");

xmlMetadataFile = ".\\data\\kml\\sea_eleph_metadata.xml";

vector<MovingObject*> output;

DataLoader::loadMovingObjects(ds, xmlMetadataFile, output);
```

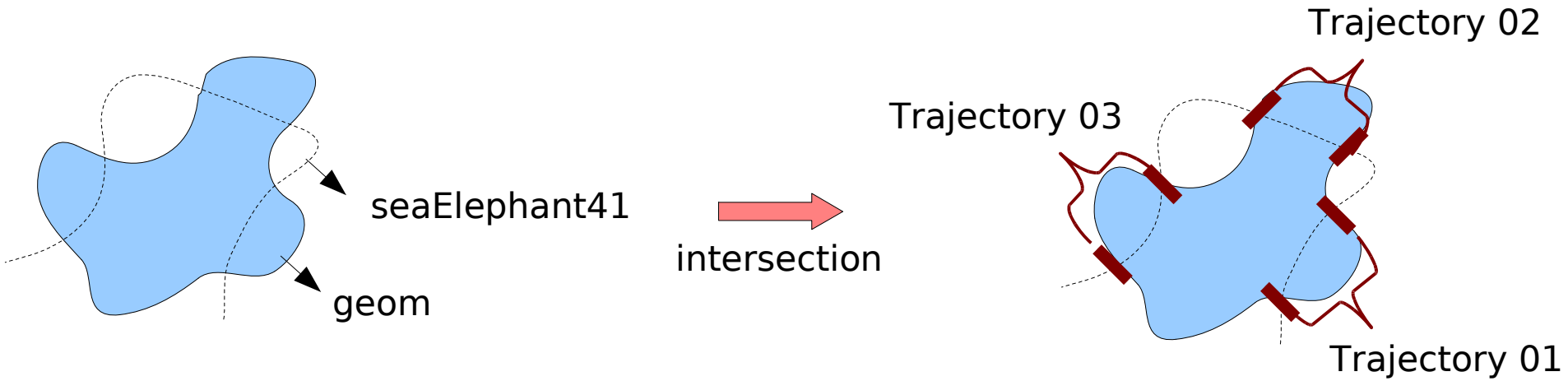
(1) OGR LIBKML Driver to read KML files
(2) Xerces-C++ to read and write XML files.

TerraLib ST module: Code example

```
MovingObject* seaElephant40 = output[0];
MovingObject* seaElephant41 = output[1];

TimeSeries* dist = seaElephant40->distance(seaElephant41);

vector<Trajectory*> trajs;
seaElephant41->intersection(geom, trajs);
```



Final remarks

- Visualization
- Patterns of trajectories
- Future