Temporal, Spatial, and Spatio-temporal Granularities

Gabriele Pozzani

Department of Computer Science, University of Verona, Italy

27th March, 2009

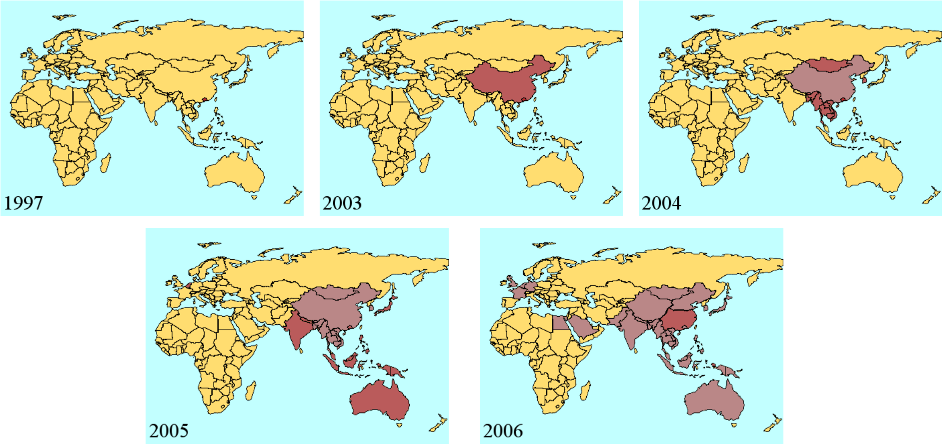
Outline

Outline

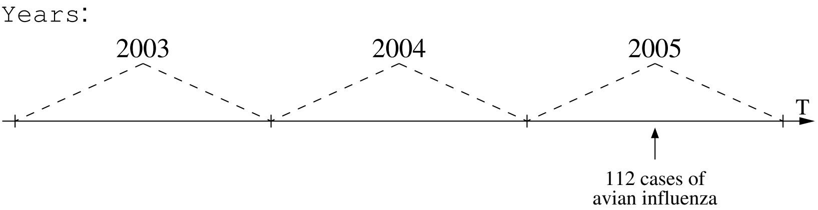
1. Introduction
2. Temporal granularity
3. Spatial granularity
4. Spatio-temporal granularity

Starting with an example

Diffusion of avian influenza



Temporal granularity + . . .



is a temporal granularity representing years.

- a temporal granularity is a partition of the time line
- each element of the partition is called granule
- each granule can be used to provide information with a time qualification

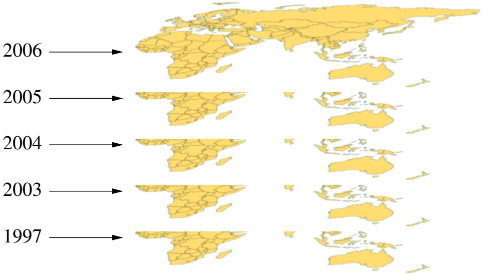
. . . + spatial granularity = . . .

Nations:

is a spatial granularity representing world nations.

- a spatial granularity is a partition of a space
- a granule in the granularity represents a region of the partition
- each granule can be used to provide information with a spatial qualification

. . . = spatio-temporal granularity



A spatio-temporal granularity represents changes in time of a spatial granularity:

- it associates a space to time
- it can be used to provide information with a spatio-temporal qualification

Outline

1. Introduction
2. Temporal granularity
3. Spatial granularity
4. Spatio-temporal granularity

Temporal granularity

Formal definition

A time domain is represented as a pair $(T, \leq)$ where

- T is a set of time instants
- $\leq$ is a total order over T

A time granularity G is defined as a mapping from an index set I to the power set of the time domain T such that:

- if $i < j$ and $G(i)$ and $G(j)$ are non-empty, then each element of $G(i)$ is less than all elements of $G(j)$;
- if $i < k < j$ and $G(i)$ and $G(j)$ are non-empty, then $G(k)$ is non-empty.

This definition was developed mainly by Bettini et al. since the last years of 1990's [BettiniDESW97]

- it is well-knows
- it is accepted by whole research community

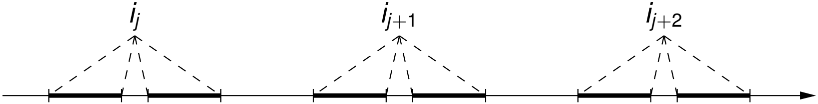
Temporal granularity

Granules

A granule is a set of instants perceived and used as an indivisible entity.

A granule can represent single instants, a time interval or a set of non-contigous instants.

`WorkingDays`:



Note: granules are total ordered, like time instants, hence navigation among granules is totally and uniquely defined.

Temporal granularity

Related notions

Origin: (of granularity G) is a specially designated granule, e.g., G(0).

Anchor: is the greatest lower bound of the set of time domain elements corresponding to the origin.

Image: of a granularity is the union of the granules in the granularity.

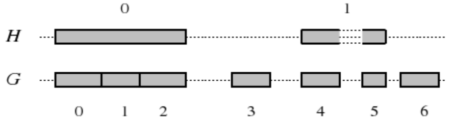
Extent: of a granularity is the smallest interval of the time domain that contains the image of the granularity. Formally, it is the set $\{t \in T | \exists a, b \in Im, a \leq t \leq b\}$ where T is the time domain and Im is the image of the granularity.

Temporal granularity

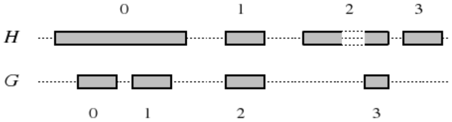
Relationships (I)

Several relations can subsist between two different granularities:

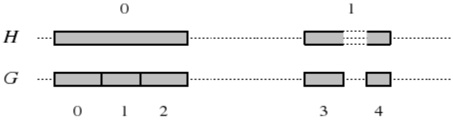
- GroupsInto



- FinerThan



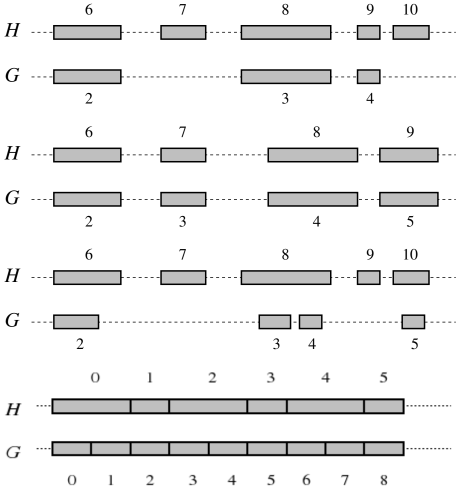
- Partitions



Temporal granularity

Relationships (II)

- Subgranularity
- ShiftEquivalent
- CoveredBy
- GroupsPeriodicallyInto



Related notions (II)

By using relations between granularities, we can define the following notions:

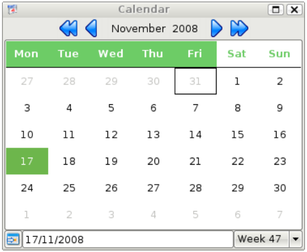
- **Bottom granularity** (w.r.t. a relationship *g-rel*): given a set of granularities having the same time domain, a granularity *G* in the set is a bottom granularity with respect to *g-rel*, if *G g-rel H* for each granularity *H* in the set
- **Lattice** (w.r.t. a relationship *g-rel*): a set of granularities s.t. for each pair of granularities in the set there exists a least upper bound and a greatest lower bound w.r.t. *g-rel*
- **Calendar**: a set of granularities over a single time domain that includes a bottom granularity with respect to *GroupsInto*

Temporal multi-granularity (I)

An example

This is a temporal multigranular system. It refers to:

- years
- months
- days
- weeks
- working days



Temporal multi-granularity (III)

Granule conversions

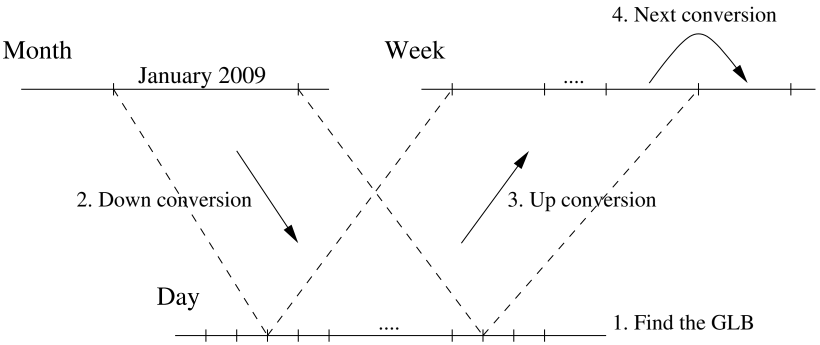
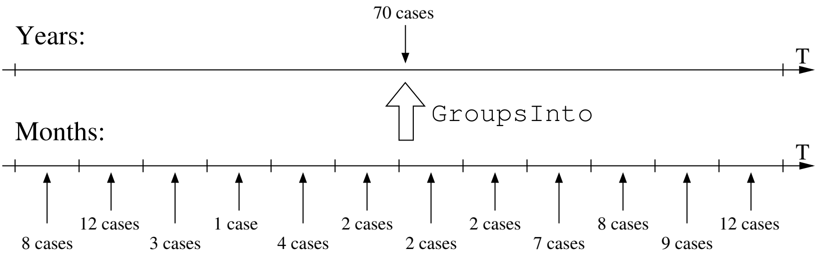


image from [NingWJ02]

Temporal multi-granularity (II)

Information conversion



Multigranularity and relationships allow one:

- to transfer information from a granularity to a related one
- to integrate information associated to different granularities and coming from different sources

Calendar algebra

In order to complete the framework for temporal granularity some operations was defined [NingWJ02].

This framework is called calendar algebra.

These operations allow one to build new granularities from other ones:

- grouping-oriented operations combine the granules of a given granularity to form the granules of a new granularity
- granule-oriented operations construct a new granularity choosing some granules from a given one
- set operations are based on the viewpoint that each granularity corresponds to a set of granules mapped from the labels. They extend over time granularities the usual set operation.

Outline

The notion of spatial granularity

Temporal vs. spatial granularities

There are deep differences between spatial and temporal granularities

- granules:
  - usually, temporal granularities are “periodical”
  - spatial granularities are not periodical and their granules may have any possible shape
- relations between granules:
  - elements of the time domain (instants) and time granules are usually ordered
  - the spatial domain supports several relations (topological relations, direction based relations,. . .)

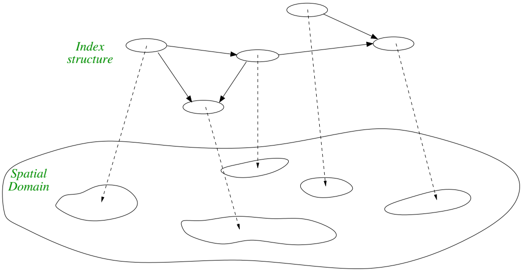
These differences require to represent and manage temporal and spatial granularities in a different way

The notion of spatial granularity

Layers

Spatial granularities have two layers:

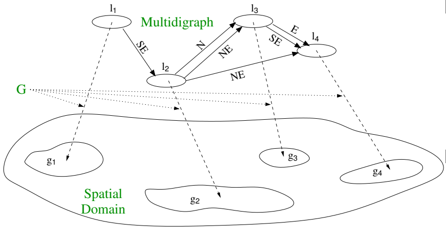
1. the spatial domain, over which we identify the regions defining granules
2. the index structure used to access and manage granules



The notion of spatial granularity

Given a spatial domain, a spatial granularity is made up of:

- a multidigraph *MG*
  - nodes represent granules
  - edges represent spatial relations between granules
- a mapping *G* that associates to each node its spatial extent
- a mapping D_A that defines for each edge label its spatial meaning
  - the edges reflect the spatial relations



Multidigraph *MG*:

- nodes: $\{l_1, l_2, l_3, l_4\}$
- edges: $\{(l_1, l_2)_{SE}, (l_2, l_3)_N, (l_2, l_3)_{NE}, (l_2, l_4)_{NE}, (l_3, l_4)_{SE}, (l_3, l_4)_E\}$

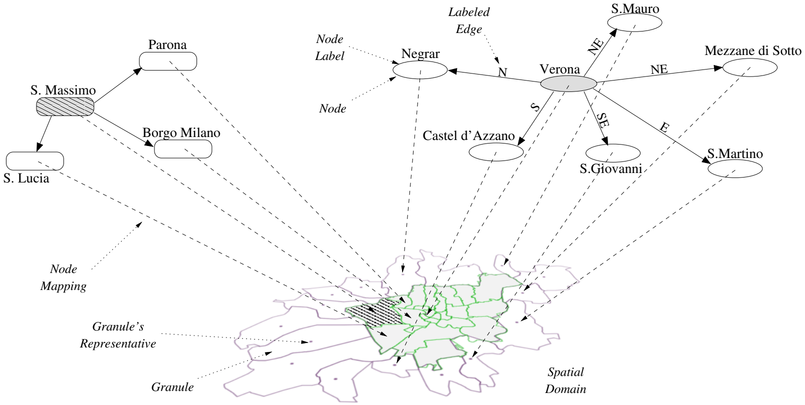
$G = \{l_1 \mapsto g_1, l_2 \mapsto g_3, l_3 \mapsto g_3, l_4 \mapsto g_4\}$

Mapping D_A:

- $N \mapsto \{(A, B) | somePoint(B)$ is up north of $center(A)\}$
- ...

The notion of spatial granularity

An example



Relations between spatial granularities (I)

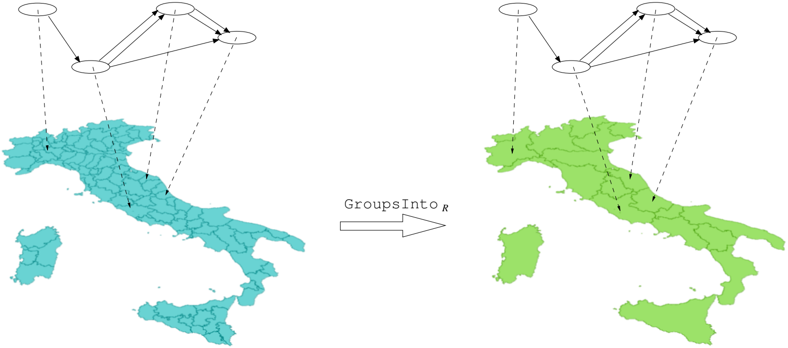
Between spatial granularities we can define several relations similar to those defined for temporal granularities:

- GroupsInto
- FinerThan
- Subgranularity
- Partition
- CoveredBy
- Disjoint
- Overlap

Some ones have also a strong version considering also the existing spatial relations between granules.

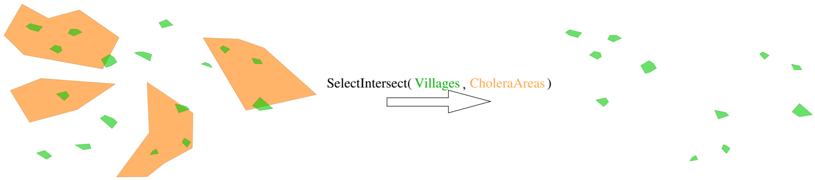
Relations between spatial granularities (II)

An example



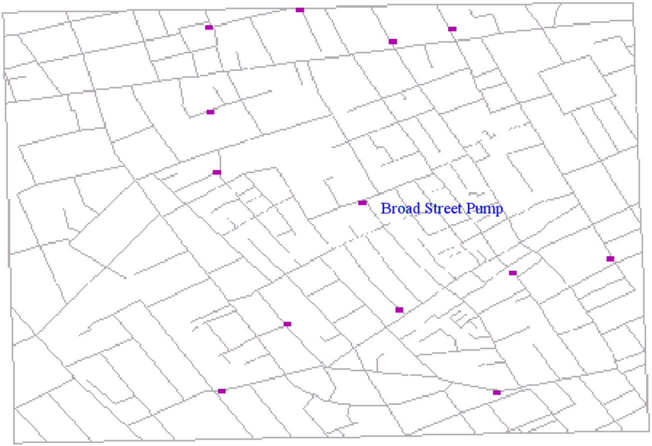
Operations between spatial granularities

Also operations over spatial granularities have been defined. These operations allow one to build new granularities from existing ones.



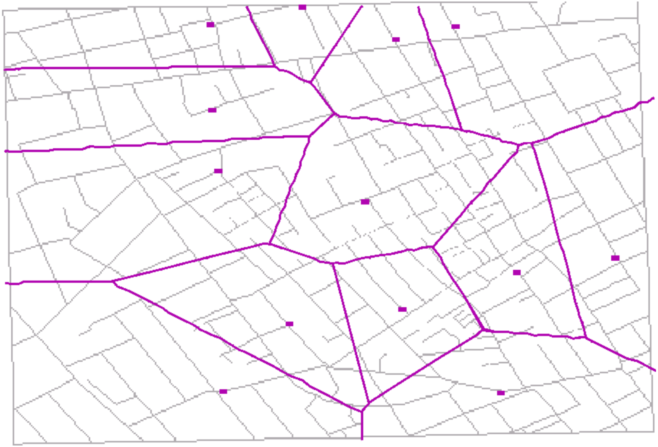
Using spatial granularities, an example

The John Snow's study about cholera cases in London, 1894



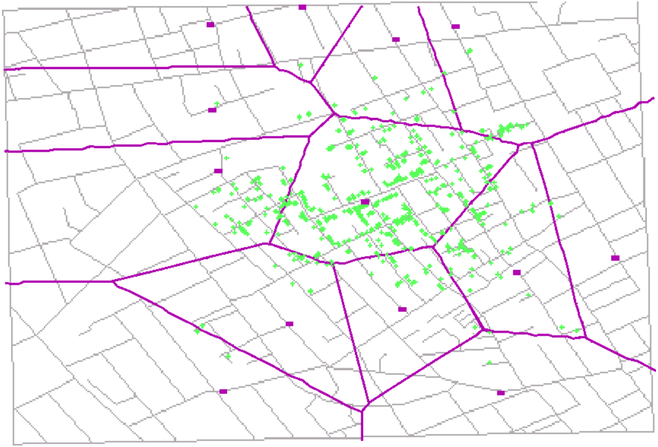
Using spatial granularities, an example

The John Snow's study about cholera cases in London, 1894



Using spatial granularities, an example

The John Snow's study about cholera cases in London, 1894



Outline

The notion of spatio-temporal granularity

Spatial evolution

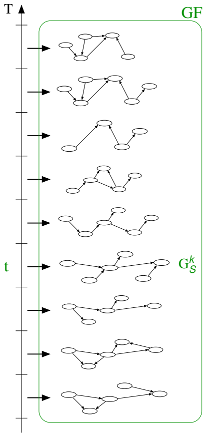
We have to represent a spatial evolution:

- for every time instant in a time domain T, a spatial evolution E maintains the spatial granularity (belonging to a family GF) that is valid at that time

$$\forall t \in T : \exists G_S^k \in GF : E(t) = G_S^k$$

we will manage the split and merge operations and trace the granules history w.r.t. the previous versions

- maintain links between the versions of each spatial granule at the different instants

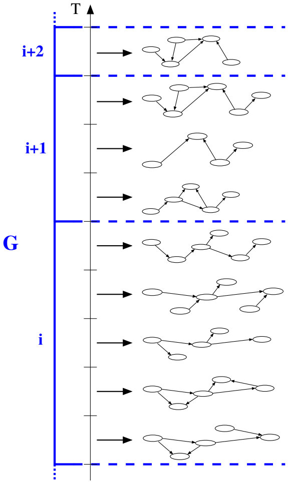


The notion of spatio-temporal granularity

A spatio-temporal granularity is made up of a temporal granularity G_T and a spatial evolution E over the temporal domain of G_T:

$$G_{ST} = < G_T, E >$$

- time instants, and then spatial granularities in the evolution, are "grouped" in temporal granules
- we can use temporal granules to manage and reason on spatial granularities
  - it is not simply a spatial granularity versioning system



The notion of spatio-temporal granularity

Advantages

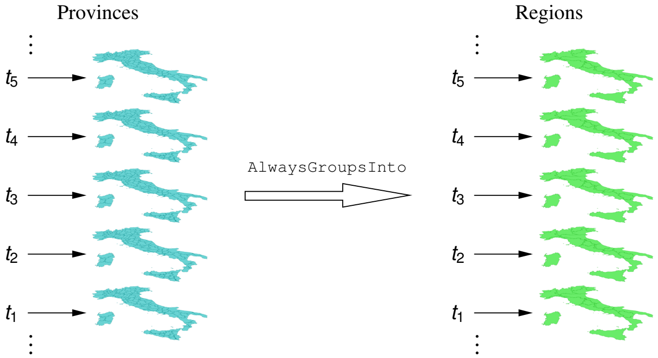
Associating a spatial granularity to each time instant:

- allows the spatial information to change during a temporal granule
- represents homogeneously several spatial evolution semantics
  - discontinuous changes (e.g. administrative divisions changes)
  - “continuous” changes (e.g. pollution areas evolution)
- allows one to build, reason on, and manage spatio-temporal granularities without loss of information just partitioning the spatial information associated to instants accordingly to the temporal granularity we are interested in

Relations between spatio-temporal granularities

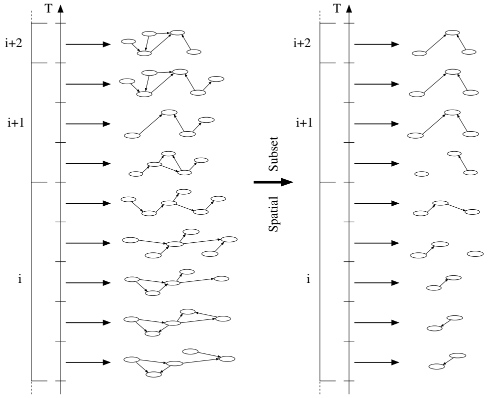
Relations are useful in order to perform spatio-temporal reasoning

- it is possible to translate information expressed by using a granularity into an equivalent information represented by another granularity



Operations over spatio-temporal granularities

Operations over spatio-temporal granularities allow one to build new granularities from existing ones. They extend spatial operations to spatio-temporal granularities combining them with time.



Thanks for your attention

Questions?

References

A. Belussi, C. Combi, and G. Pozzani.
"Towards a formal framework for spatio-temporal granularities",
Temporal Representation and Reasoning, 2008. TIME '08. 15th International Symposium on, pp. 49–53, June 2008.

P. Ning, X. S. Wang, and S. Jajodia.
"An algebraic representation of calendars",
Ann. Math. Artif. Intell, vol. 36, no. 1-2, pp. 5–38, 2002.

C. Bettini, C. E. Dyreson, W. S. Evans, R. T. Snodgrass, and X. S. Wang,
"A glossary of time granularity concepts",
LNCS, vol. 1399, pp. 406–413, 1998.

E. Camossi, M. Bertolotto, and E. Bertino.
"A multigranular object-oriented framework supporting spatio-temporal granularity conversions",
International Journal of Geographical Information Science, vol. 20, no. 5, pp. 511–534, 2006.