Generalisation of point data for mobile devices:
A problem-oriented approach

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Outline

1. Defining the point generalisation problem

2. Algorithms for point generalisation

3. A workflow for mobile point generalisation
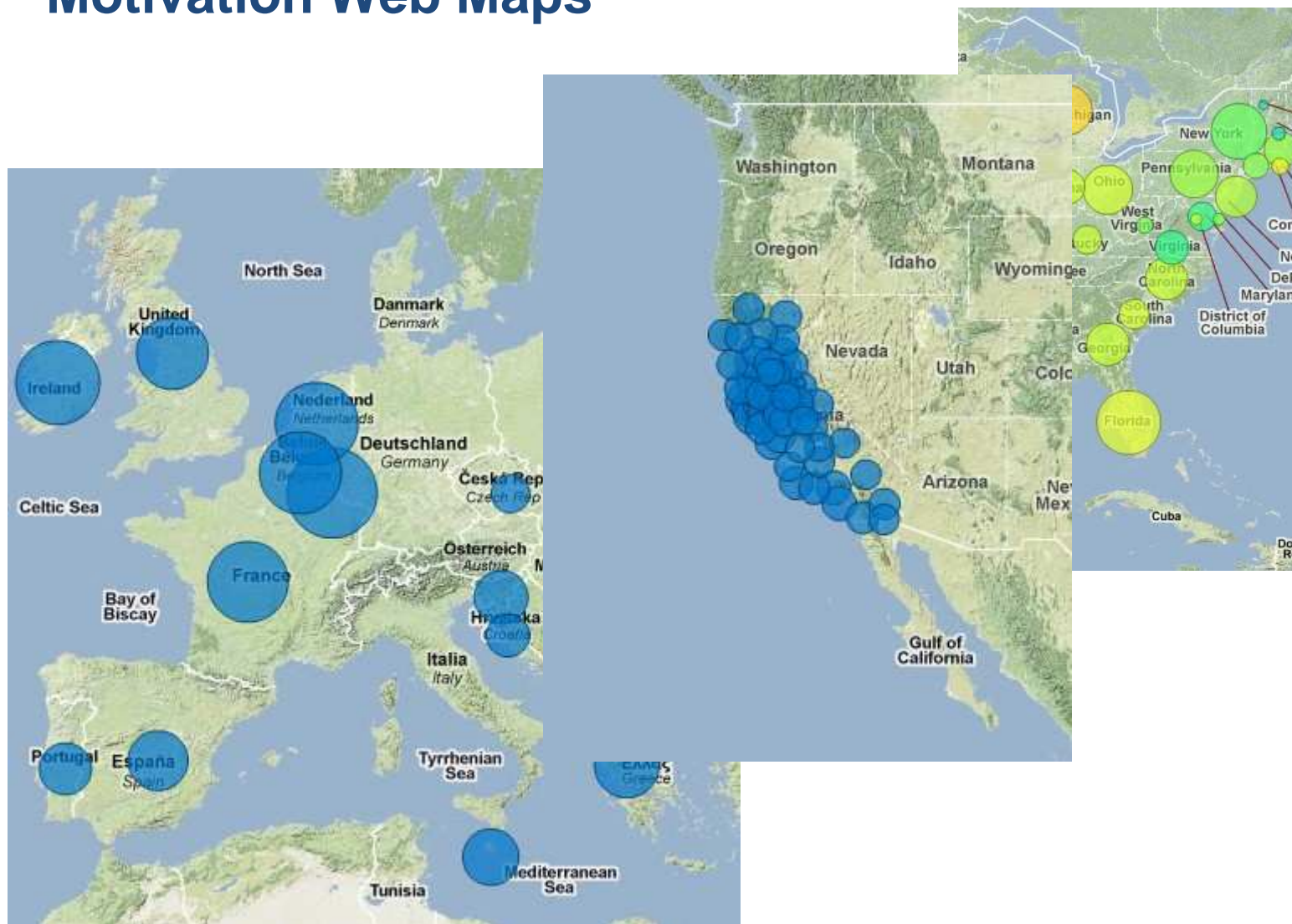
4. Research questions and research plan

Objective

Analyse & compare different approaches (algorithms and data structures) for point generalisation for mobile devices

Motivation Web Maps

Motivation Web Maps

Google public data explorer
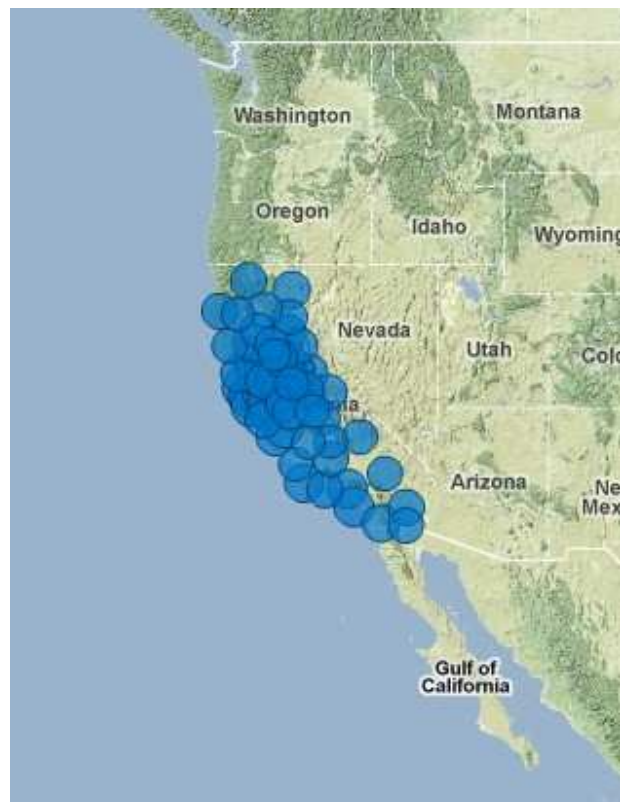GDP and Personal Income
of the US (annual)
http://www.google.com/publicdata

Motivation Web Maps

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Motivation Web Maps

Source: http://gridskipper.com/archives/entries/261480/261480.php

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Motivation Web Maps

Source: http://www.spatialdatabox.com/map-demos/starbucks-map.html

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Motivation Web Maps

Canadas Economic Action Plan
http://www.spatialdatabox.com/map-demos/canada-economic-action-plan-map.html

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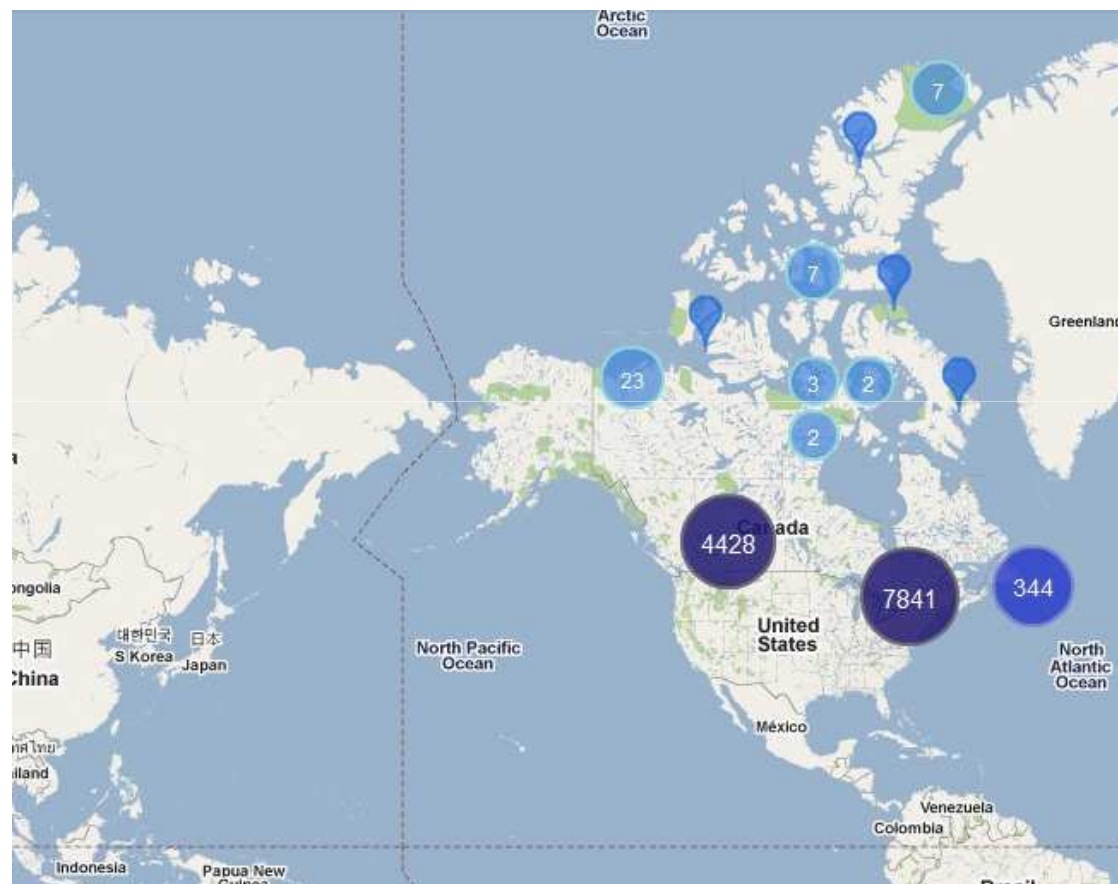
Motivation Web Maps

Canadas Economic Action Plan
http://www.spatialdatabox.com/map-demos/canada-economic-action-plan-map.html

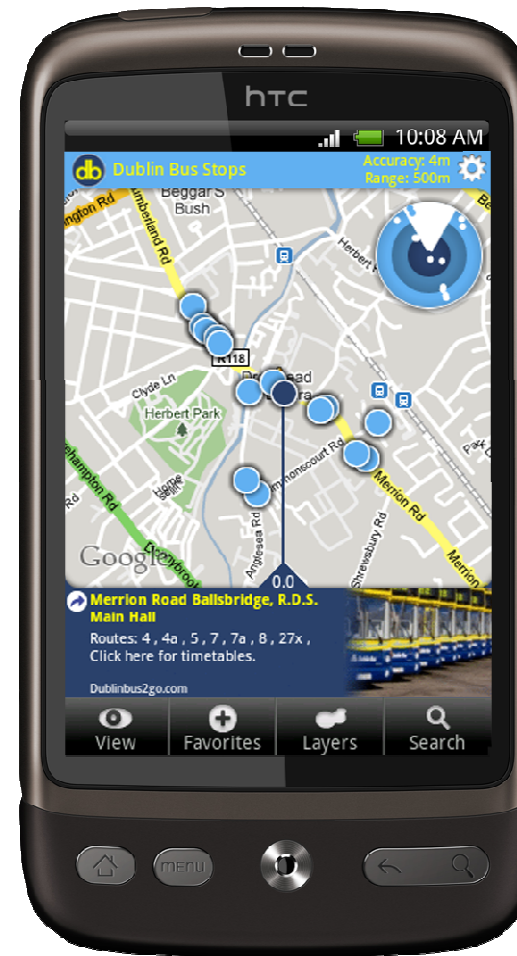# Motivation Web Maps

http://www.spatialdatabox.com/map-demos/usgs-gnis-map.html

Motivation Mobile Maps

Motivation Mobile Maps
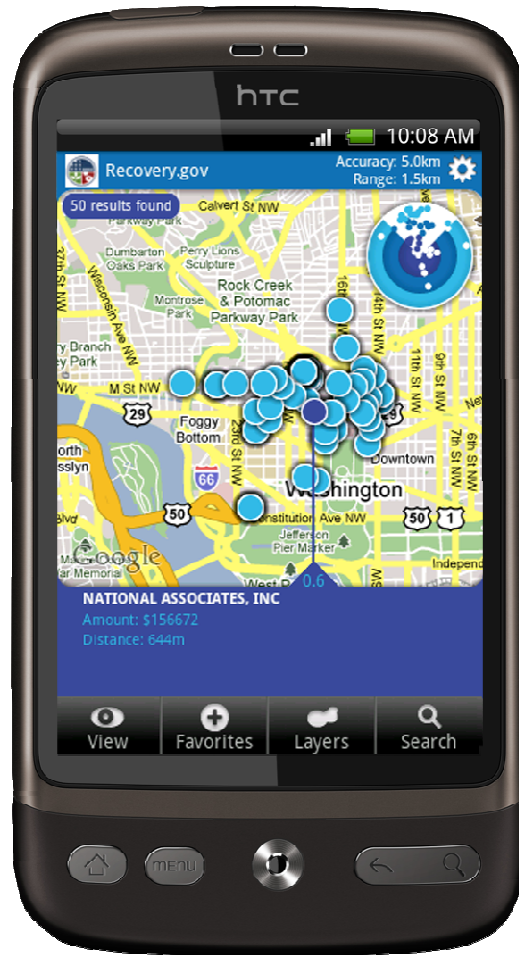
Layar mobile browser / augmented reality

Defining the point generalisation problem

Defining the point generalisation problem

Background versus foreground data	Types of point data
Constraints on point data	Level of interactivity

Defining the point generalisation problem

Background versus foreground Data

Source:http://www.swisstopo.admin.ch/internet/swisstopo/de/home/products/maps/mobile/mobile_iph/screenshots_mobile_iph.html

Defining the point generalisation problem

Types of point data

Defining the point generalisation problem
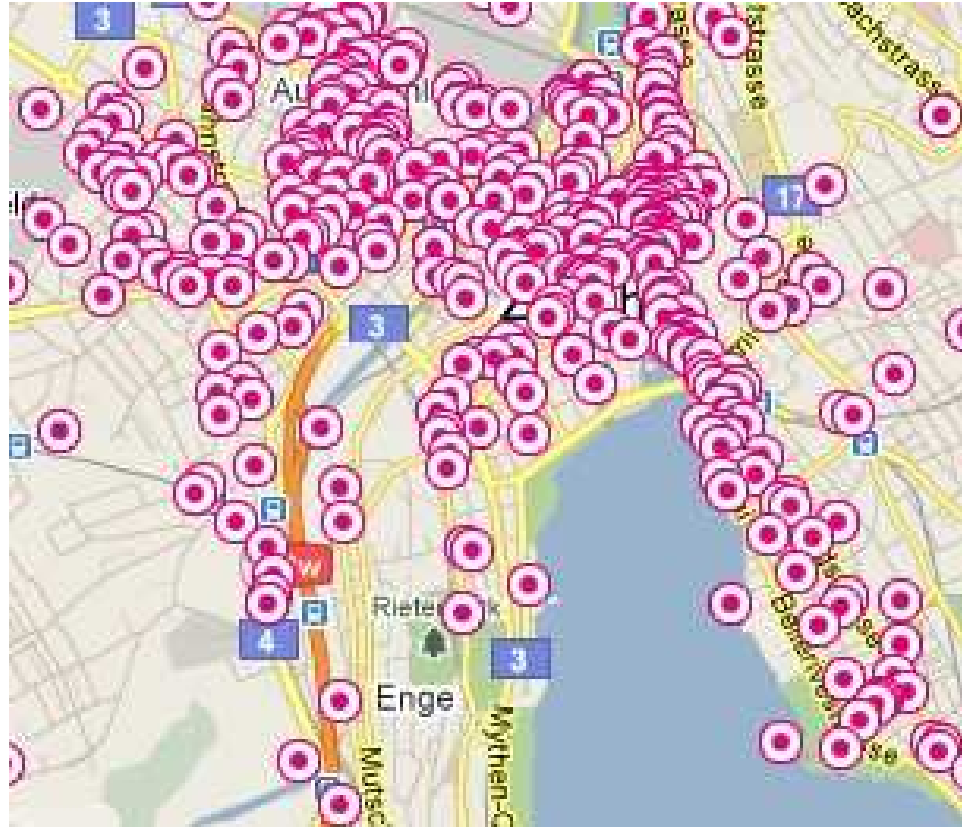
Constraints on

point data

Source: http://www.zueritipp.ch/gastro

Defining the point generalisation problem

Constraints on

point data

Source: http://www.zueritipp.ch/gastro
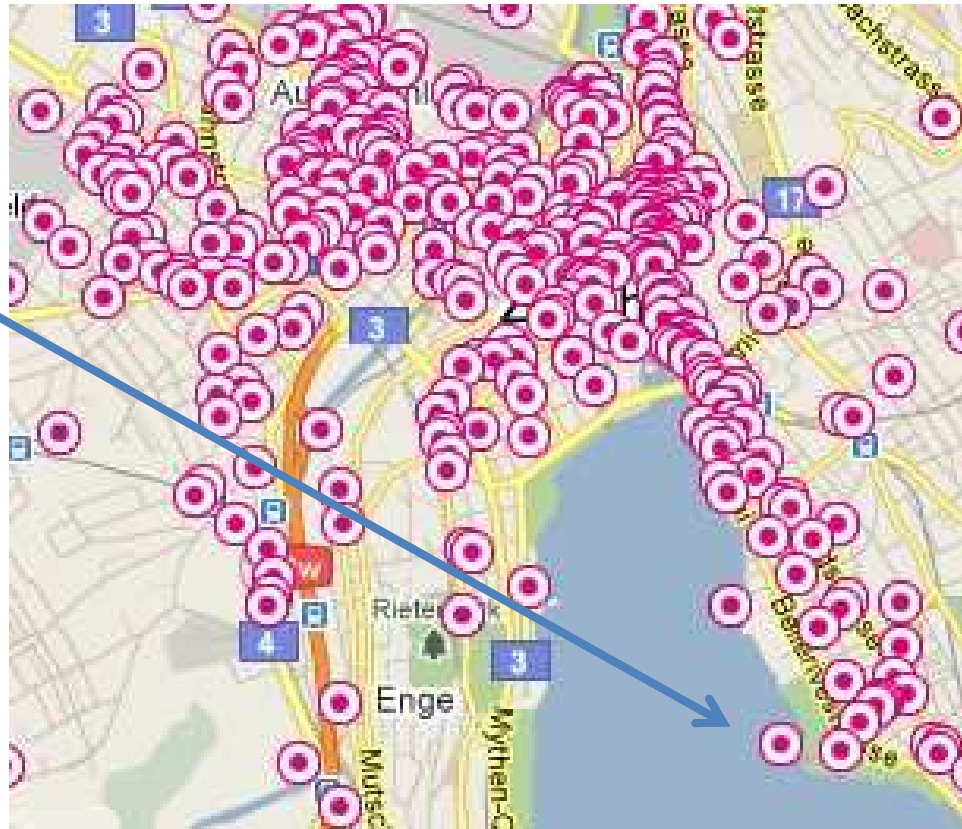
Defining the point generalisation problem

Level of
Interactivity
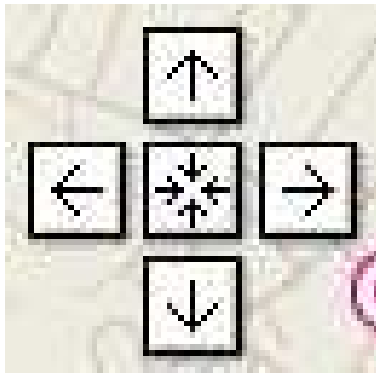
The higher the interactivity, the more can be adjusted and 'cleaned up' on the map, the more sub-optimal generalisation quality can be tolerated

Algorithms for point generalisation

Transformation focus

Transformation principle

Generalisation operations

Original point features

Object-directed transformation focus

Space-directed transformation focus

Point reduction

Point displacement

Malleable space

Focal transformation

Selection

Simplification

Aggregation

Typification

Displacement
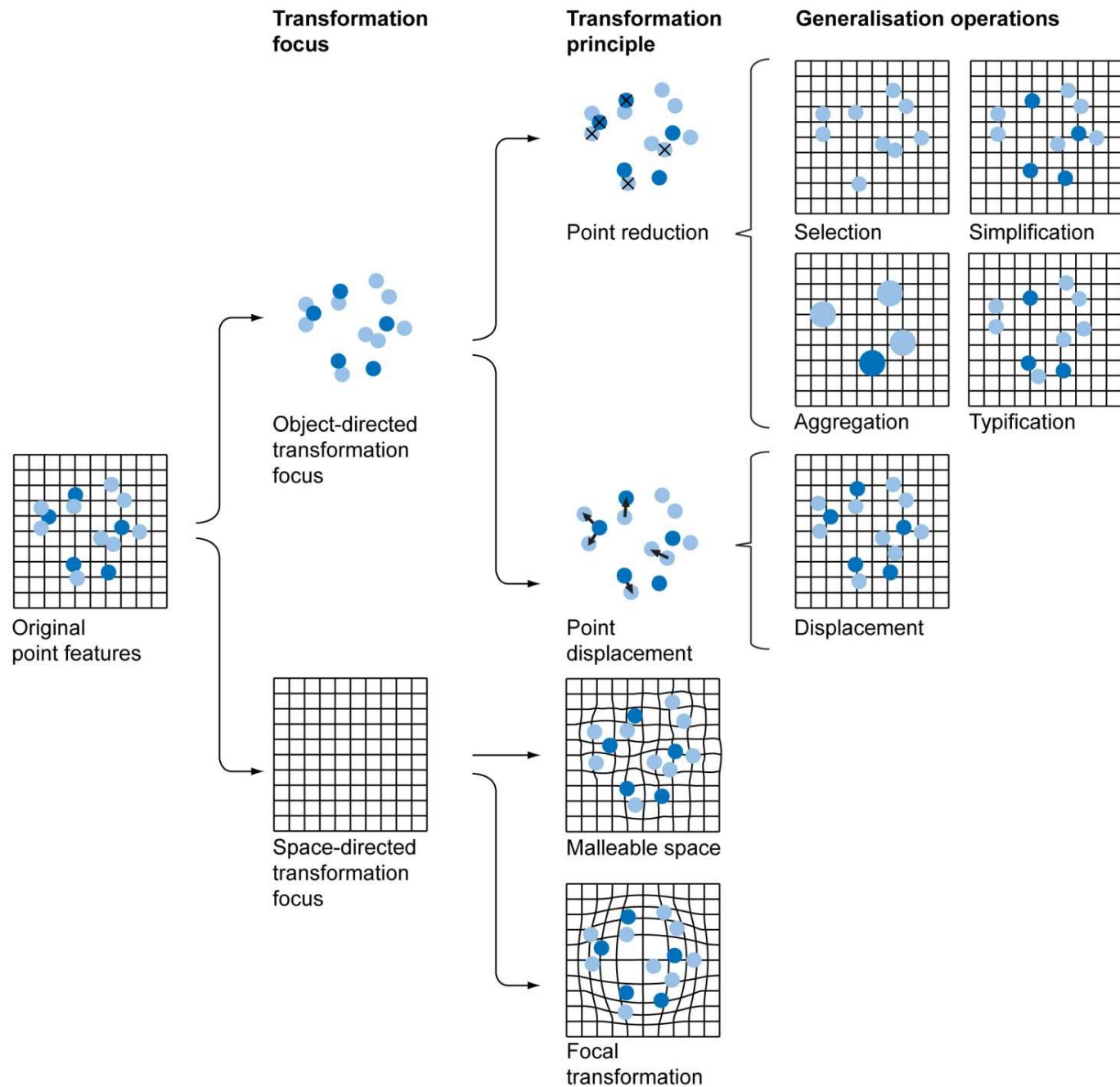
Space-directed versus Object-directed transformation focus
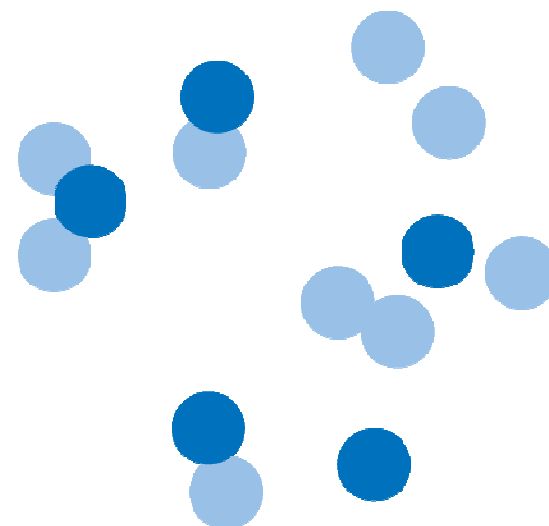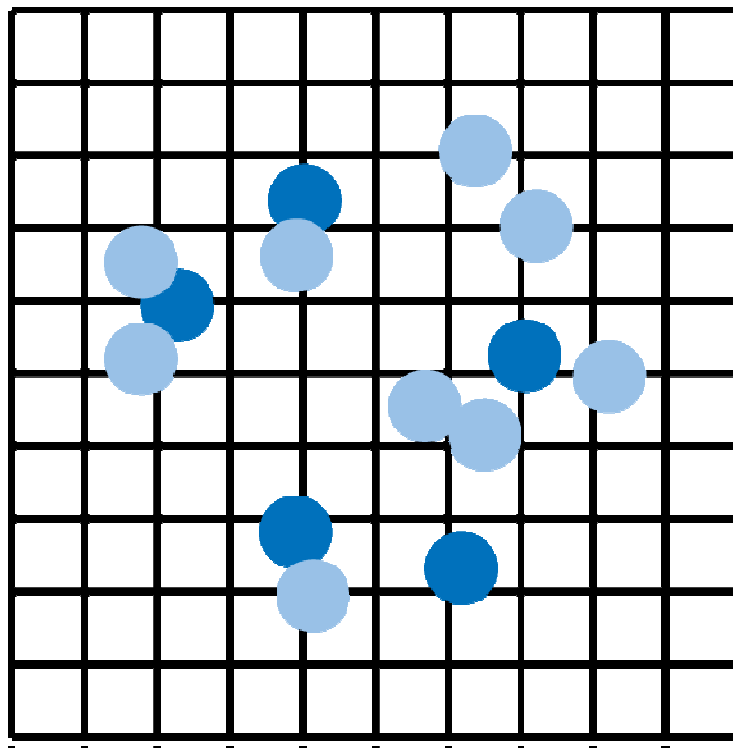
Space-directed versus Object-directed transformation focus
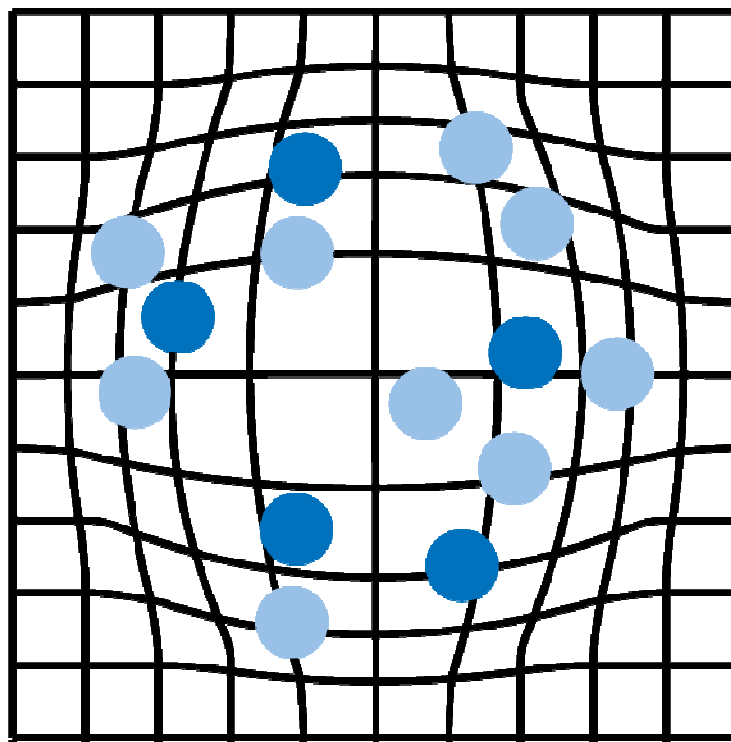
Space – directed Approach
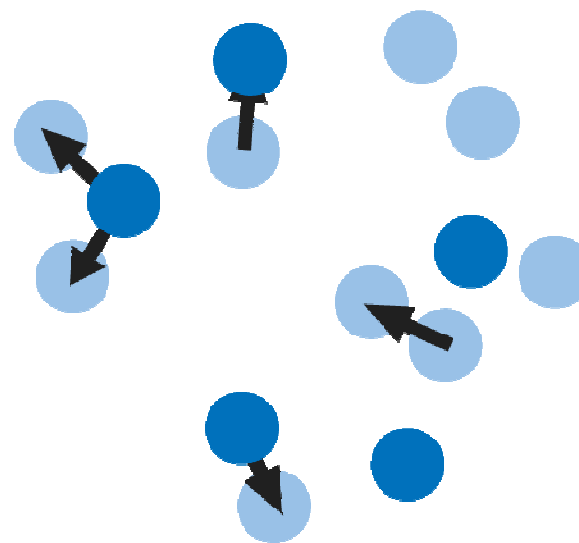
Object – directed Approach

Algorithms with an object-directed transformation focus
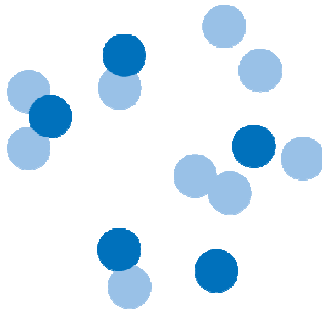
Point reduction

- Selection

- Simplification

- Aggregation
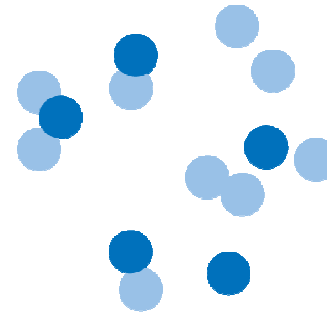
- Typification

Point displacement

Algorithms with an object-directed transformation focus
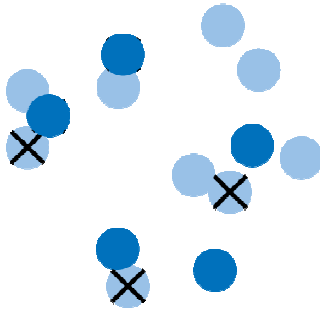
Point reduction

- Selection
- Simplification
- Aggregation
- Typification
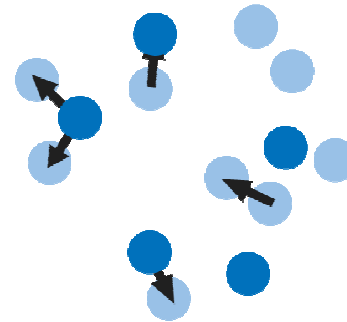
Point displacement

Approaches based on a space-directed transformation focus
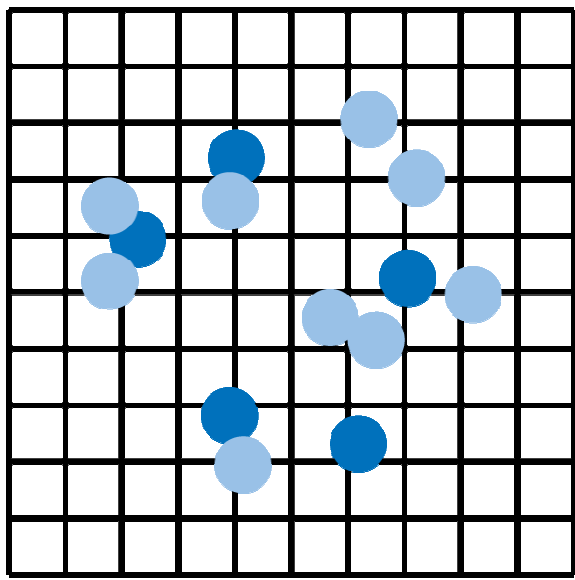
Spatial deformation (local)
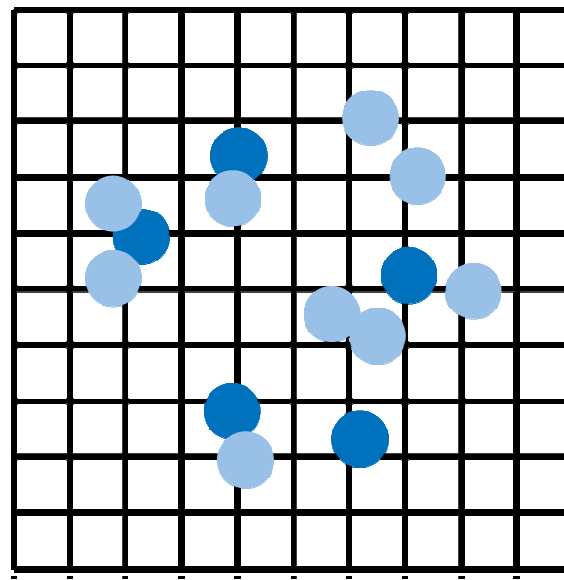
Focal projections (global)

Approaches based on a space-directed transformation focus
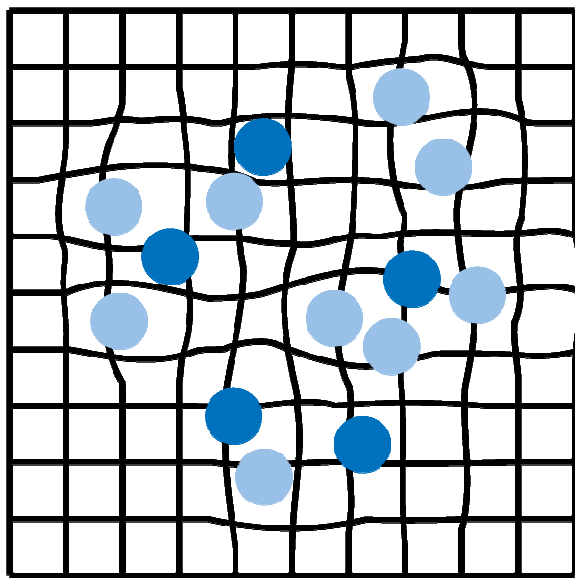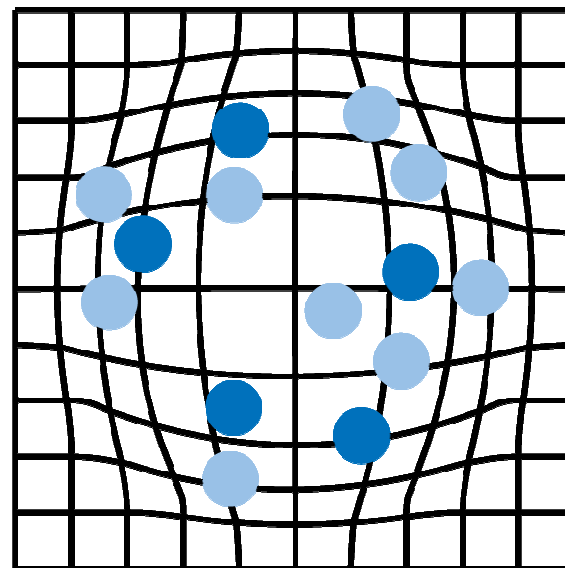
Spatial deformation (local)   Focal projections (global)

Workflow for Mobile Point Generalisation

Workflow for Mobile Point Generalisation

Execute generalisation

Define resources

Generalisation strategy

Define the purpose of the map

Trans-formation focus

- Content – conservative approach
- Balanced – approach
- Space – conservative approach

- Object – directed
- Space – directed

Strategy for point generalisation

The **content conservative** approach

The **balanced** approach

The **space conservative** approach
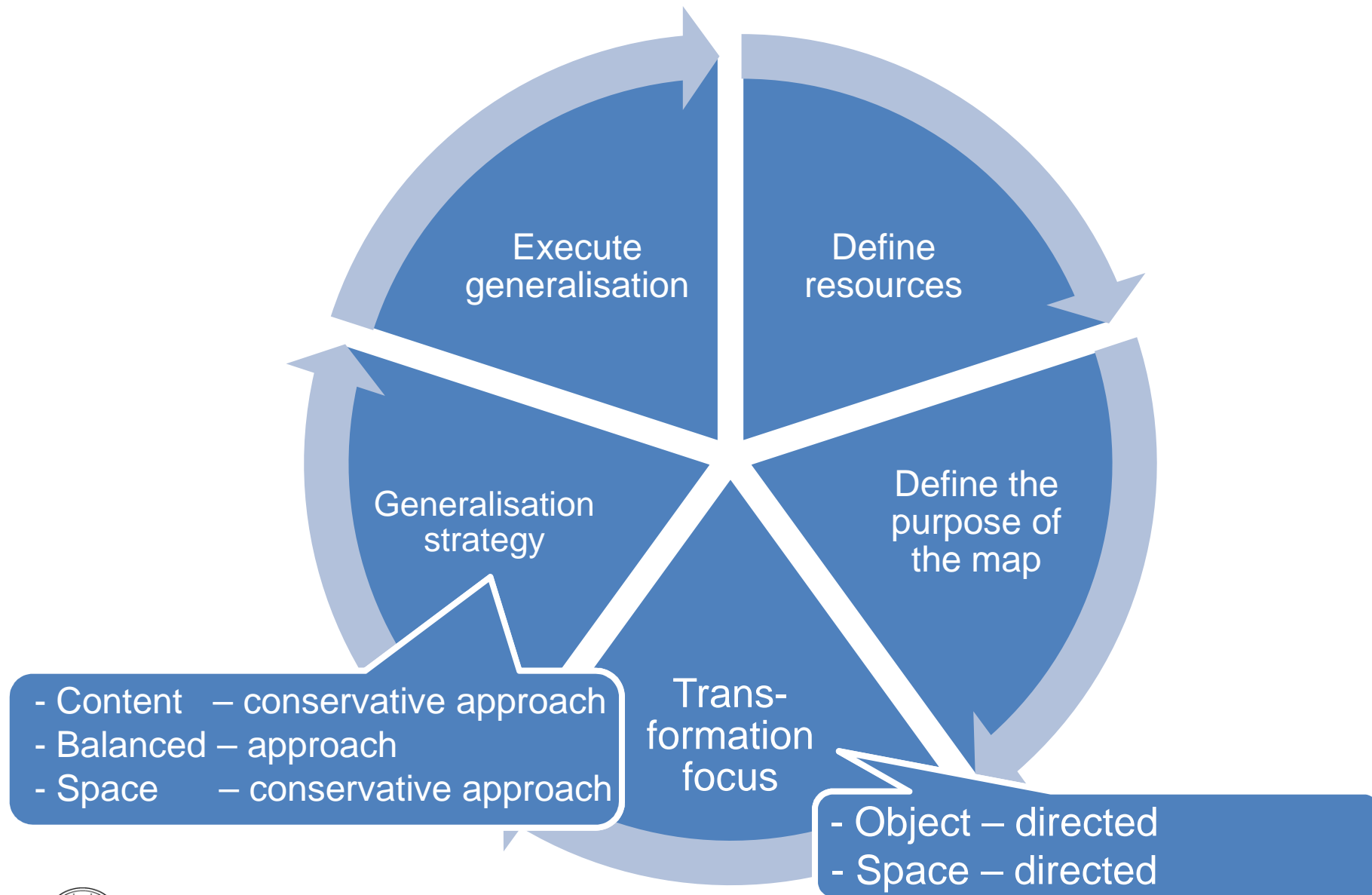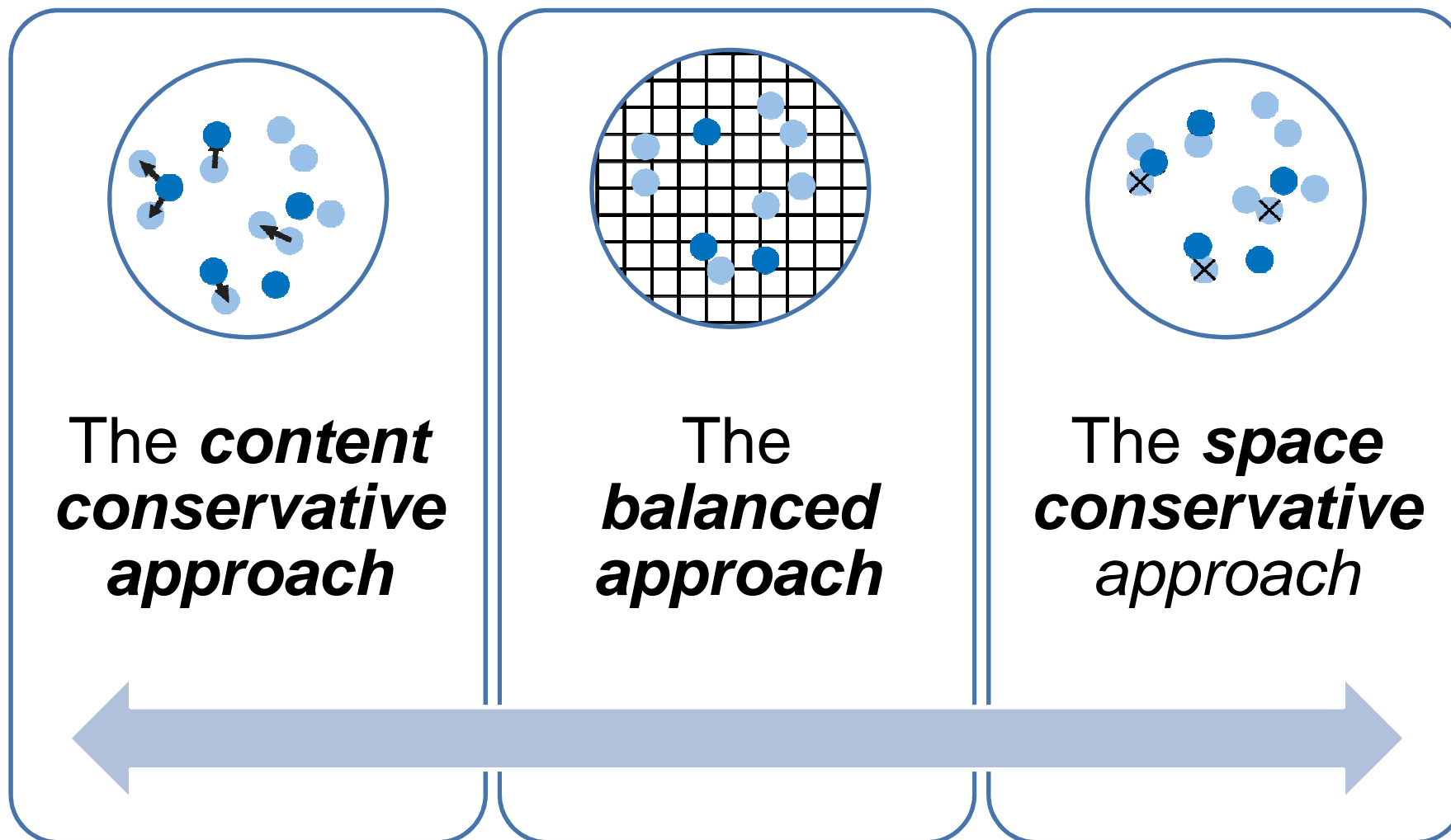
Research questions

Which algorithms for point generalisation have potential for real-time execution?

How do the different strategies for point generalisation affect map reading tasks (in terms of efficiency and accuracy)?

How useful and usable are the generated displays?

How is the cartographic quality of the results evaluated by cartographers vs. lay users?

Searching for candidate algorithms

Selection of candidate algorithms that have potential

for real time generalisation

Literature review

Selected Algorithms

Type	Candidate
Selection	**Quadtree, streamordering** (Burghardt 2004) swapping, quadtrees, clustering, dobkin-tal,simulated annealing(de Berg 2004), **R-tree** (Guttmann 2984), Mesh Simplification (Hoppe 1996), Horton (Mazur 1990, Horton 1945), **KD-tree**
Simplification	XML transformation (Lehto 2001, 2005), Douglaus Peuker, Lang, Gaussian(Sarjakoski 2005), adaptive zooming (Cecconi/Galanda 2002), Mustafa 2004, progressive Vector data (Yang/Purves/Weibel 2007)
Typification	**Mesh simplification, Delaunay** (Burghardt 2007, Cecconi 2003), Strahler ordering, Watershed catchment (Edwardes 2005), Voronoi (Yang Weibel)
Displacement	**Iterative** (Mackaness/Ross 2001), Morphing (Monmonier 1989), Agent (Jabeur 2006), Snakes (Bader 2001, Burghardt 2005), Elementary Operations (Sester,Brenner 2004)
Aggregation	**K-means**, k-means++, Iterativ closest point R-tree… (Mannes 2004, Anders 2003, Arthur 2009) KDE?
Focal Transformation	Variable-scale -with selection (Harrie 2002) yamamoto 2009, karthik 2004
Malleable Space	**Laplacian Smoothing** (Edwardes 2007)

Selected Algorithms

Type	Candidate
Selection	**Quadtree, Stream ordering** (Burghardt 2004), **R-tree** (Guttmann 1984), **KD-tree** (Sester, Sarjakowski, Harrie 2004)
Typification	**Mesh simplification** (Burghardt 2007, Cecconi 2003)
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Aggregation	**K-means** (Mannes 2004, Anders 2003, Arthur 2009)
Malleable Space	**Laplacian Smoothing** (Edwardes 2007)

Testset for candidate algorithms

Implement & use existing algorithms

Improve / adapt / add new algorithms

Compare & test algorithms for real-time performance
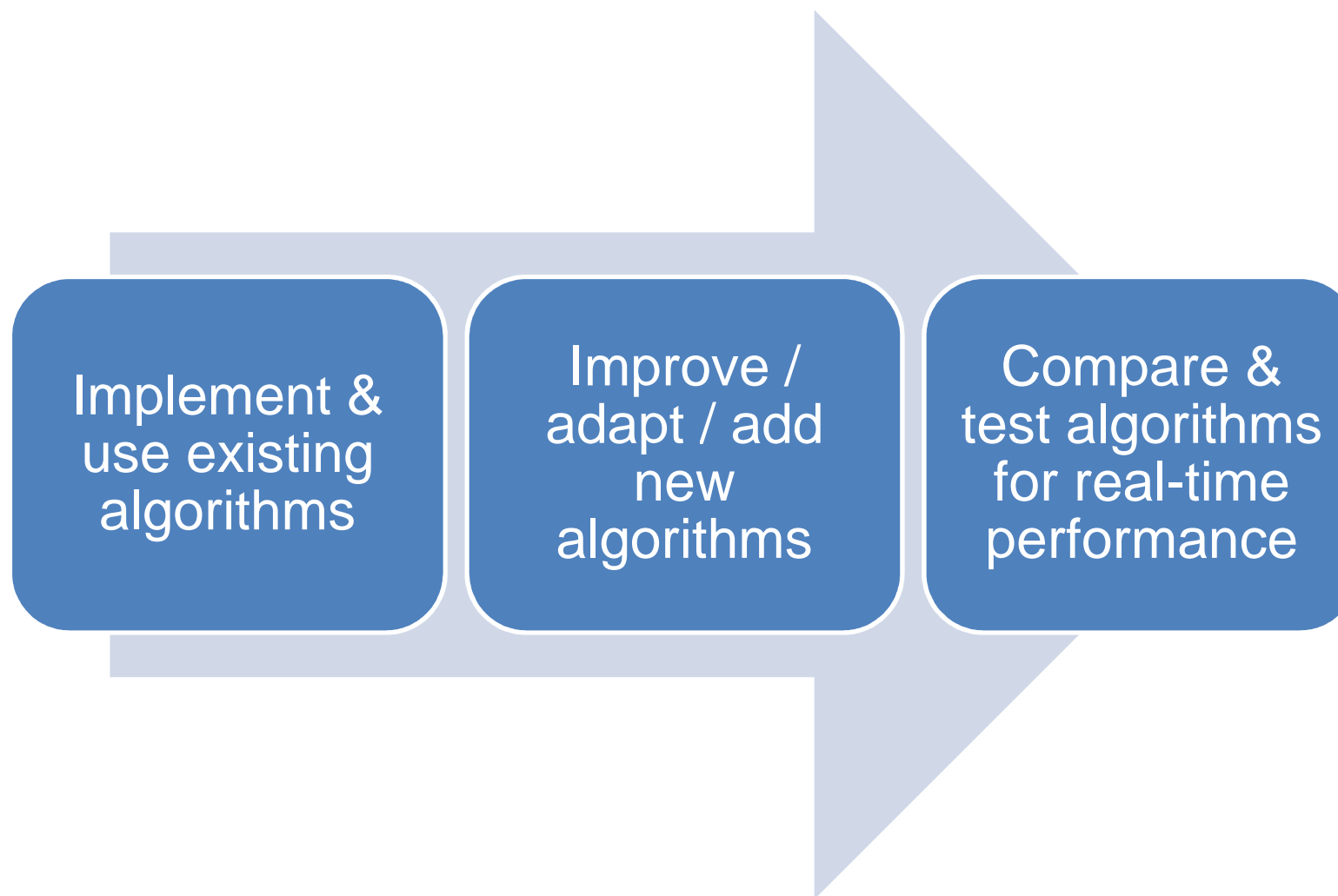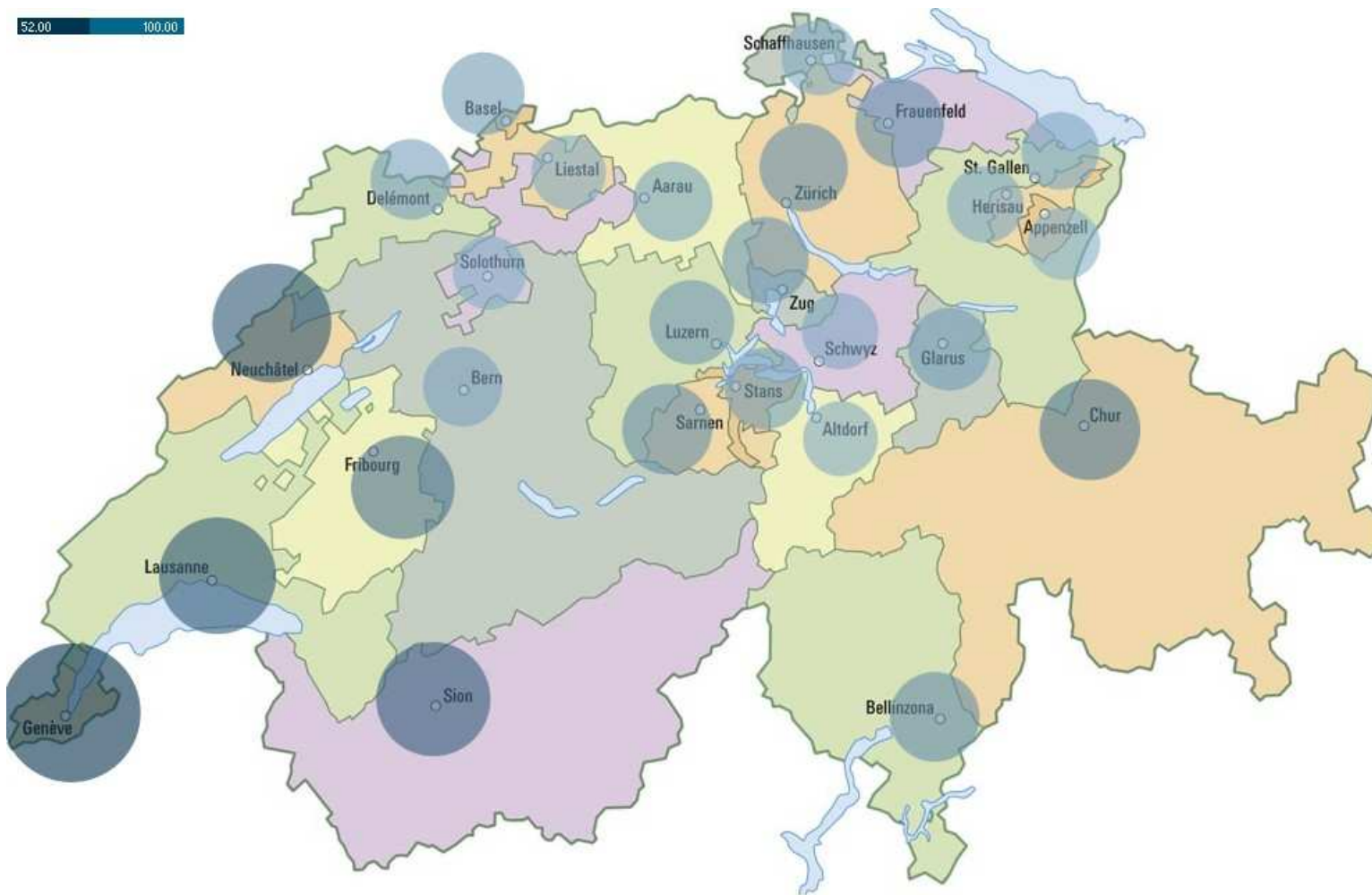
Algorithms

Kantonskarte geodata © swisstopo

Reliefkarte geodata © swisstopo

Evaluate Algorithms

1. Empirical evaluation of the cartographic quality (cartographers, lay users)

2. Test usefulness and usability of the generated displays in task-based user studies

   Compare generalisation strategies / quality / usability

   1. Usability tasks: find, compare, estimate, evaluate

   2. Aesthetics: paired comparison, ranking, Likert scale

   3. Preference for strategy: Let user choose based on data and map types

   4. Generalisation: let the user generalise

Summary

Classification of algorithms – approaches for point generalisation

Selection of candidate algorithms that have potential for real time generalisation

Implementation of a test bed

Compare algorithms for real-time generalisation of point data for mobile device

Classification and within compared algorithms select those that are optimal for real-time generalisation

Next Steps

Testset for candidate algorithms

Empirical evaluation

- Cartographic quality

- Test usefulness and usability of the generated displays in task-based user studies

Fast slow – food
or
slow fast – food?

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Thank you for listening

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Focus and Strategy

The **transformation focus defines whether to select an approach based on an object-directed or space-directed transformation focus.**

strategy for point generalisation

- The *content conservative approach tries to retain as many point features as possible on the map and prioritises displacement as a generalisation operator. It assumes that the point features have been previously filtered to a sufficiently small number.*

- The *balanced approach resolves spatial conflicts by aggregating point features and is better suited for highly interactive maps that need a larger 'interaction footprint' per point feature.*

- The *space conservative approach tries to avoid displacement of point features and prioritises selection and typification as generalisation operators.*

Workflow for Mobile Point Generalisation

1. Define resources

2. Define the purpose of the map

3. Transformation focus

    1. Object – directed

    2. Space – directed

4. Generalisation strategy

    1. Content – conservative approach

    2. Balanced – approach

    3. Space – conservative approach

5. Execute generalisation