A Simulated Annealing Algorithm For Cartographic Map Generalization With Multiple Operators

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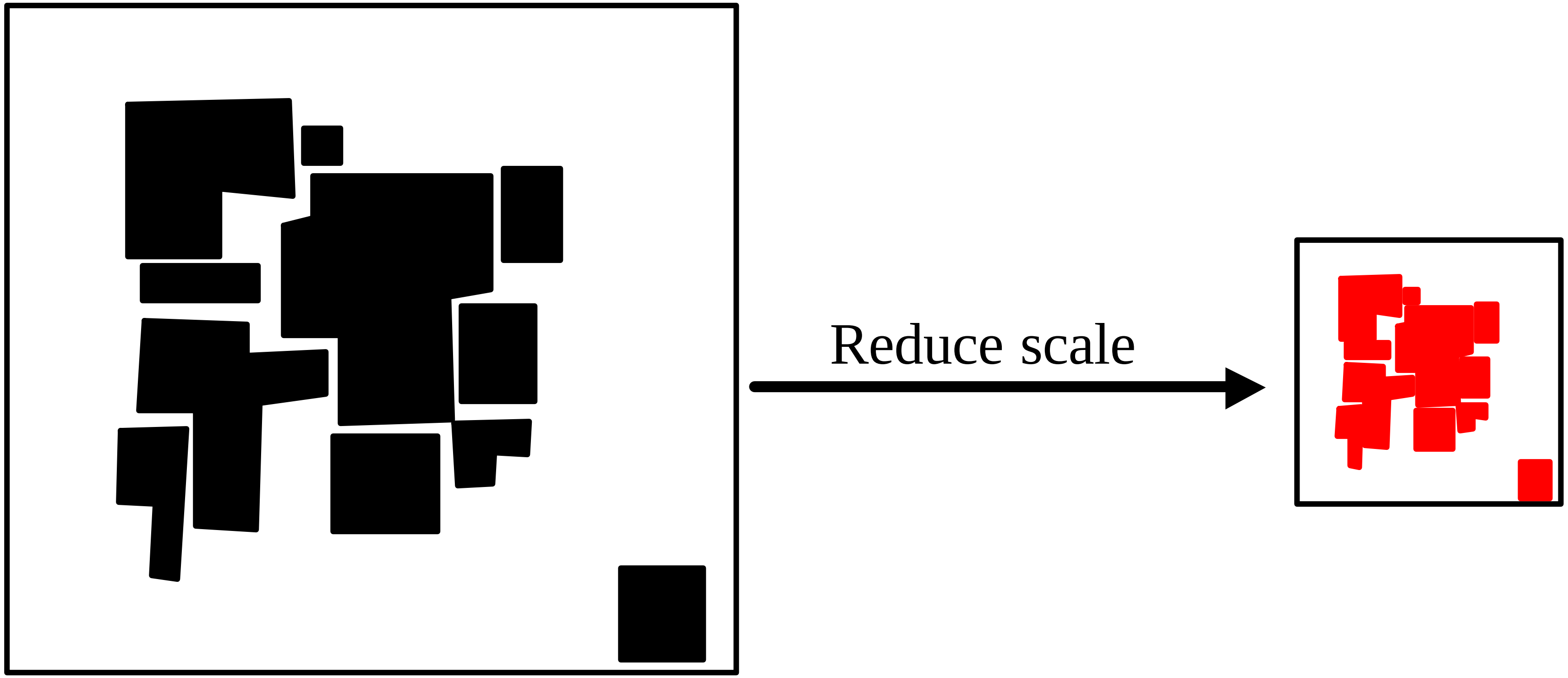
Ordnance Survey

THE PROBLEM



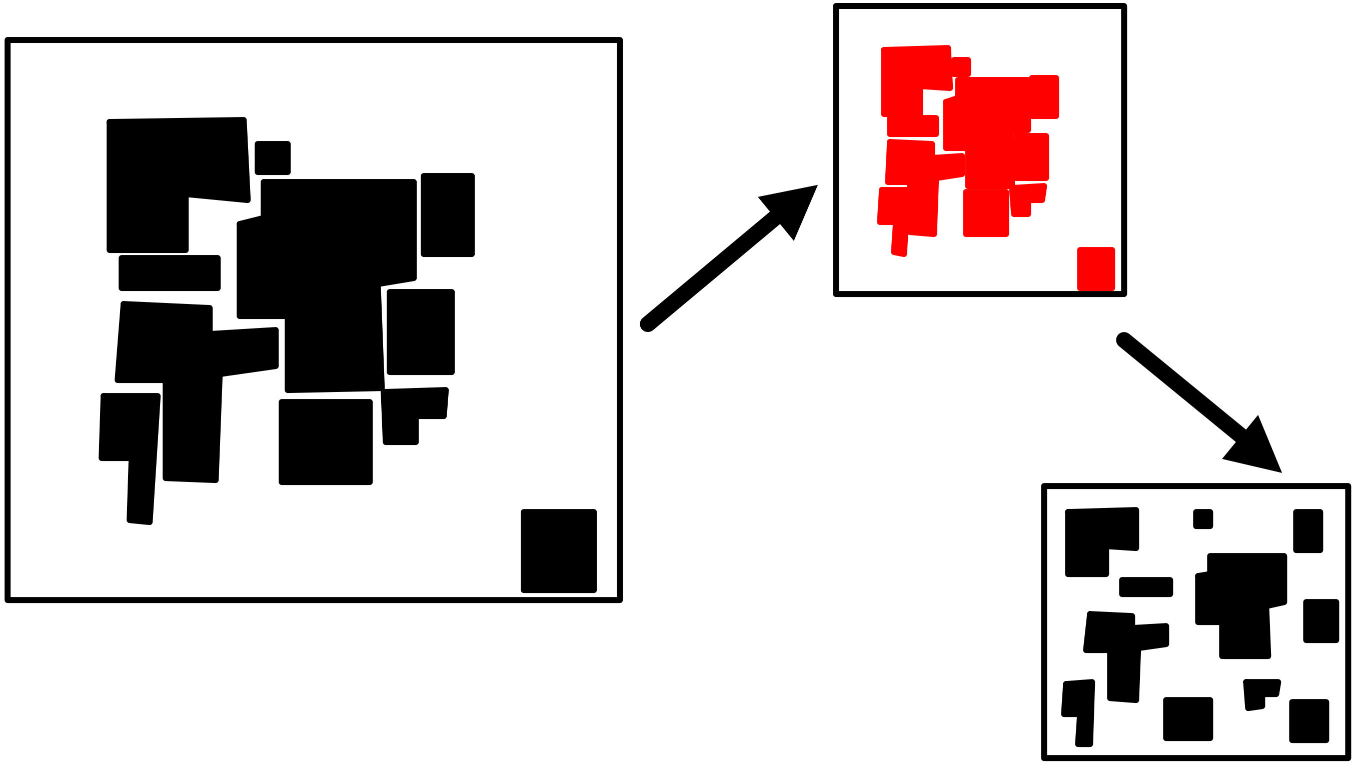
spatial conflict due to

– objects lying too close to each other

MAP GENERALIZATION - THE SOLUTION

- simplification
- amalgamation
- reduction
- typification
- deletion
- displacement
- resize

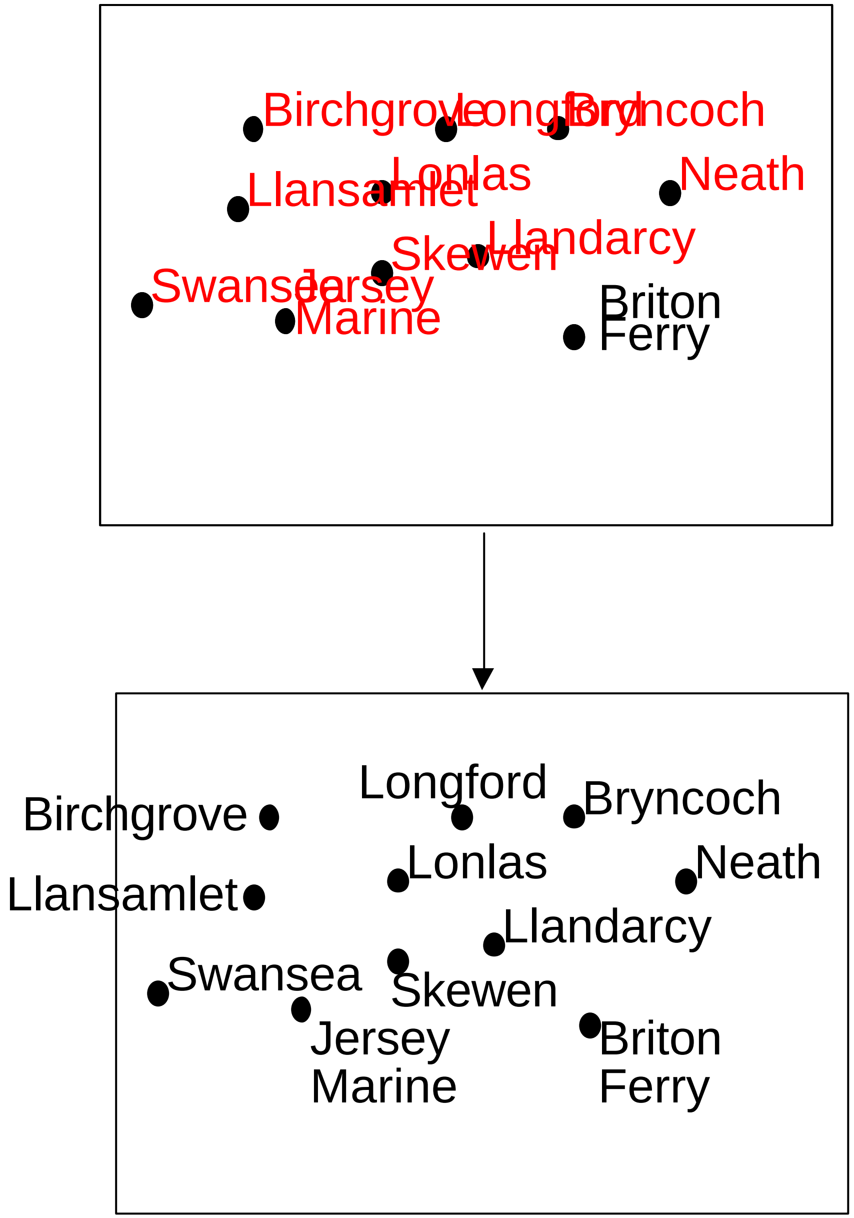
CONFLICT RESOLUTION BY OBJECT DISPLACEMENT

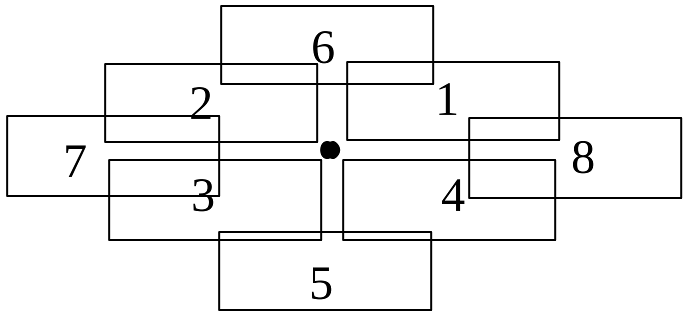


resolve by displacing one or more objects
(assume it is permissible to move each object up to a predefined maximum distance from its origin)

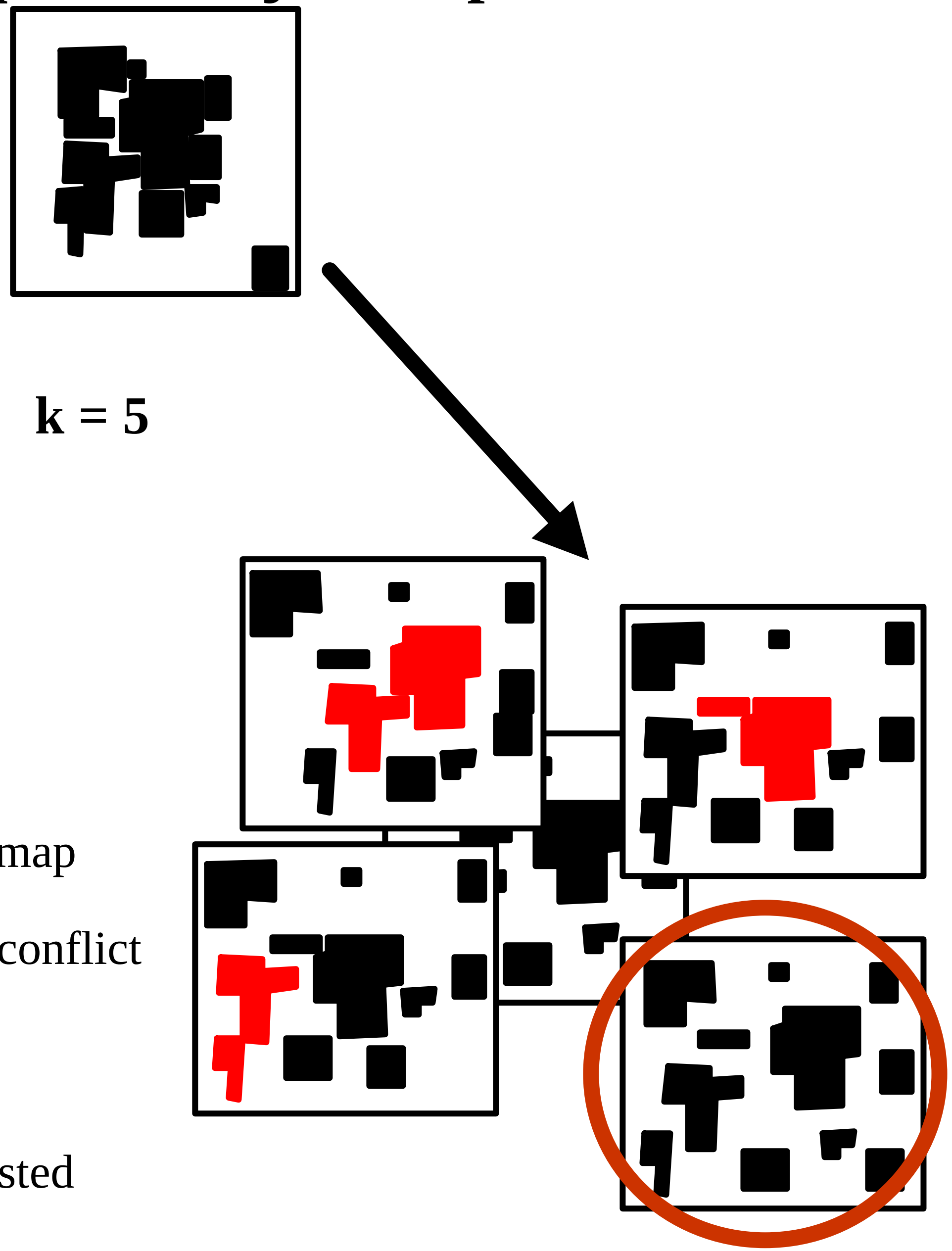
OBJECT DISPLACEMENT USING TRIAL POSITIONS

Point Feature Label Placement Using Trial Positions



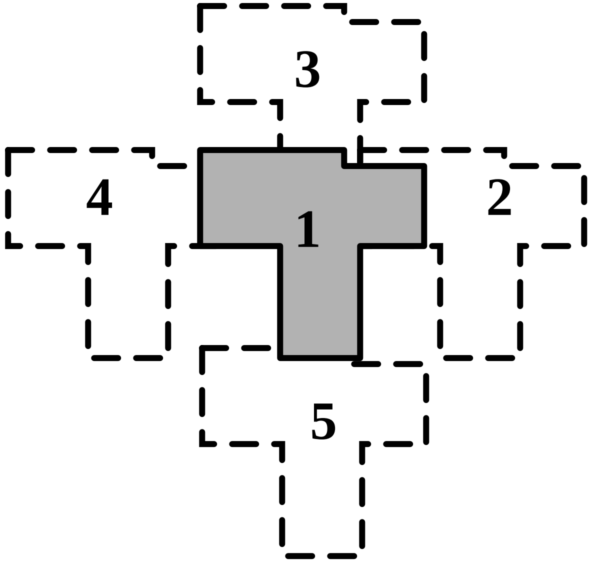


Apply PFLP trial position techniques to Object Displacement



- we have map, n objects, containing conflict

- assign each object k trial positions



k = 5

- there will be k^n alternative realisations of the map

- hopefully some will contain reduced levels of conflict

- too many to generate and test all

(e.g. k=8, n =10, > 1 billion configurations)

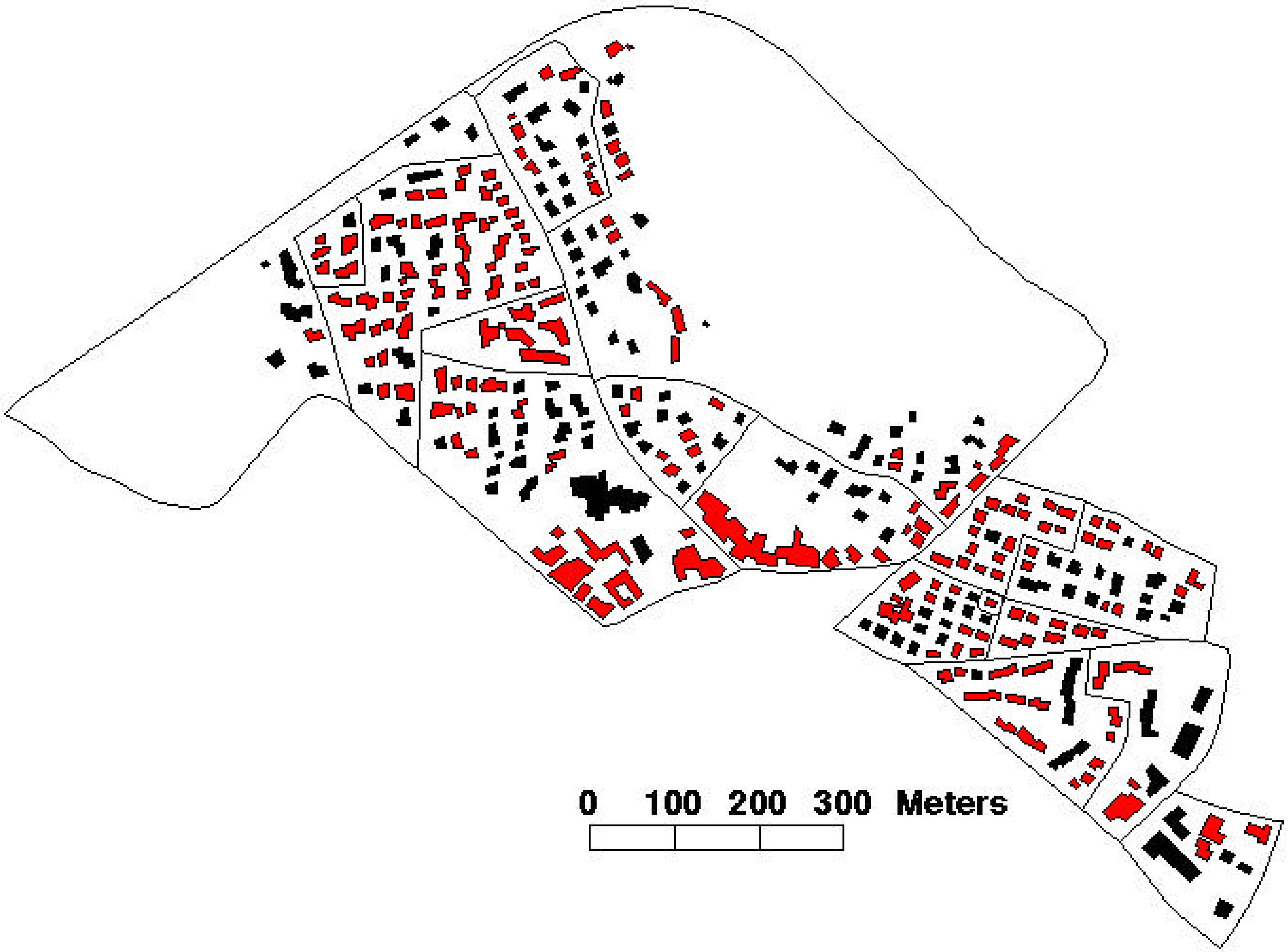
-need some strategy for limiting number tested

A SIMULATED ANNEALING APPROACH

function **SimulatedAnnealing**

input: $D_{initial}$, Schedule, Stop_Conditions

$D_{current} \leftarrow D_{initial}$
T$\leftarrow$**initialT**(Schedule)
while **NotMet**(StopConditions)
    $D_{new} \leftarrow$**RandomSuccessor**($D_{current}$)
    $\Delta E \leftarrow$**C**($D_{current}$)-**C**(D_{new})
    if $\Delta E > 0$ *then* $D_{current} \leftarrow D_{new}$
    else
        $P = e^{-\Delta E / T}$
        R=Random(0,1)
        if (R<P) *then* $D_{current} \leftarrow D_{new}$
    end
    T$\leftarrow$**UpdateT**(Schedule)
end
Return($D_{current}$)


0 100 200 300 Meters


0 30 60 90 Meters


0 100 200 300 Meters


0 30 60 90 Meters

DISPLACEMENT COST


0 30 60 90 Meters


0 30 60 90 Meters


0 30 60 90 Meters

ADDITIONAL OPERATORS

DELETION


0 30 60 90 Meters


0 30 60 90 Meters

IMPORTANCE WEIGHTING


0 30 60 90 Meters


0 30 60 90 Meters

SCALE/RESIZE


0 30 60 90 Meters


0 30 60 90 Meters

COST SETTING


0 10 20 30 Meters


0 10 20 30 Meters


0 10 20 30 Meters


0 10 20 30 Meters


0 10 20 30 Meters

CURRENT AND FUTURE WORK

- **Additional operators**
  e.g. amalgamation

- **Additional feature types**
  e.g. lines

- **Constraints**
  e.g. feature alignment

- **Higher/global level control**
  e.g. staggered use of operators

- **Alternative optimisation**
  e.g. tabu

EXECUTION TIME IMPROVEMENT

Original Simulated Annealing Results

- Total number of configurations = 29^{321}

- Number of configurations evaluated = 342000

- Average Cost = 27 (best result = 22)

- Time taken = 40s (as reported in GeoInformatica 1998)

  - too slow !

Improvement 1 - run on a faster machine

- Total number of configurations = 29^{321}

- Number of configurations evaluated = 341000

- Cost = 26

- Time taken = 13.5s

Improvement 2 - segment data

•Number of configurations evaluated dictated by annealing schedule and problem complexity

•Annealing schedule -

- –Initial temperature T
- –Number of evaluations at each temperature
- –Temperature reduction factor

•Difficult problem will require many configurations

i.e. annealing schedule - high initial T
- many evaluations at each temperature
- small reductions in T

•Simple problem will require few configurations

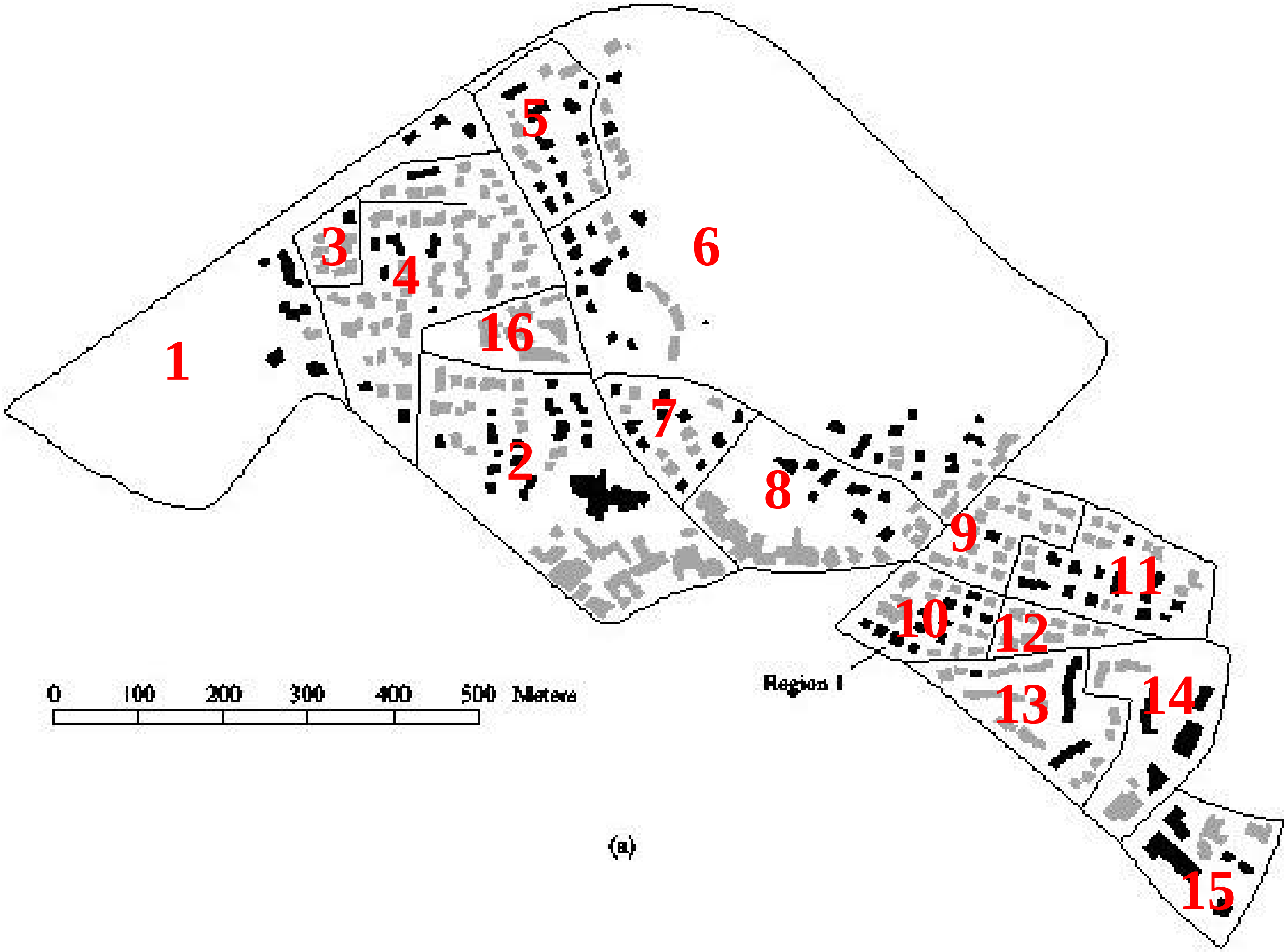
i.e. annealing schedule - low initial T
- few evaluations at each temperature
- large reductions in T

•If data is processed as a whole, annealing schedule must be set so at to be able to deal with most difficult part of data - leading to processing redundancy in parts where problem is simple

•Segment data - a separate, appropriate, annealing schedule for of each data subset

•Data segmented into autonomous regions
i.e. an object in a particular region can never come into conflict with object belonging to any other region

Data segmented into 16 autonomous regions



Segmentation Results

•Total number of configurations = 29^{321}

•Number of configurations evaluated = 79000

•Cost = 27

•Time taken = 3.2s

- 75% saving

Problem

- Each of 16 annealing schedules arrived at via experimentation

- Need some method for automating the setting of annealing parameters (lots of work on this in general SA literature, such as automated setting of initial temperature T)

Improvement 3 - two stage annealing

•Simulated annealing

- high temp gets you to a low cost area is solution space
- low temp gets you to the local minimum

•Many authors suggest low temperature start annealing

-Need some method to stop solution from immediately getting caught in a local minimum

•Two stage annealing - replace annealing actions taking place at higher temperatures with a faster heuristic algorithm

-fast heuristic algorithm - locates low cost area in solution space
-simulated annealing (low initial T) - locates local minimum

TSSA algorithm

Stage 1

simulated annealing

- high initial temperature
- rapid cooling

Stage 2

simulated annealing/sintering

- low initial temperature
- gradual cooling

TSSA Results

- Total number of configurations = 29^{321}
- Number of configurations evaluated = 74000
- Cost = 26
- Time taken = 3.1s
  - 75% saving

Improvement 4 - combine segmentation & TSSA
(i.e. apply TSSA to each of the 16 regions in turn)

- Total number of configurations = 29^{321}
- Number of configurations evaluated = 37000
- Cost = 26
- Time taken = 1.6s
  - 88% saving