Image Pattern Matching and optimization using simulated annealing: a Matlab Implementation

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Contents of Presentation

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Motivation for pattern matching

- Advent of ever increasing spatio-temporal resolutions.
- Lack of quick, automated and reliable information mining methods.
- Image pattern matching – a key research area in CBIR
- Simulated annealing (SA) – a widely applied technique for optimization, now applied to spatial domain also.
- Geostatistics – represents spatial structure in the best possible manner
Research Questions

- Can we obtain similar matching patterns in objects of images through process of optimization of images through SA?
- Can we use variogram as an optimization function in SA process?
- How to execute this in Matlab?
- How to optimize the code for performance (processing time, memory)
- What all issues to consider to make the code generic and flexible?
Research Objectives

Main Objectives:
- Given a satellite image, obtain another image with similar matching pattern
- Explore potential of variogram as an optimization function
- Implement the whole methodology of SA in Matlab

Sub Objectives:
- A flexible & generic SA implementation w.r.t inputs & outputs
- Code optimization for performance w.r.t processing time and memory
- Evaluation of SA implementation on several images from several sites/times/trees/areas/configurations/no. of objects.
4 stage Implementation

- Image pre-preprocessing
  - Binarization of tree canopy boundaries.
  - Image rotation and cropping image area.

- Image Simulation
  - Extraction of information on number and inter-spacing between objects

- Variogram Calculation
  - Omni & Directional variograms
  - Angle & Distance tolerances, Cutoff range definition

- Simulated Annealing
Simulated Annealing

- Motivated by the physical annealing process
- Material is heated and slowly cooled into a uniform structure
- Simulated annealing mimics this process
- The first SA algorithm was developed in 1953 (Metropolis)

Spatial Simulated Annealing

- SA carried out for Spatially Explicit Processes
- Kirkpatrick (1982) applied SA to optimisation problems
- SSA requirements
  - Initial Temperature
  - Initial solution
  - Cooling schedule
  - Acceptance criterion
  - Stopping criterion
  - Spatial Optimization function
### SSA Parameters in our case

<table>
<thead>
<tr>
<th>S. No.</th>
<th>Parameter Name</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>h (decay factor)</td>
<td>1024</td>
</tr>
<tr>
<td>2</td>
<td>Cooling Rate</td>
<td>0.9995</td>
</tr>
<tr>
<td>3</td>
<td>$d_{\text{max}}$</td>
<td>Diagonal distance normalized by square root of number of circles</td>
</tr>
<tr>
<td>4</td>
<td>Precision (for stopping criteria)</td>
<td>6 places after decimal (0.000001)</td>
</tr>
<tr>
<td>5</td>
<td>Max iterations with allowed moves (for stopping criteria)</td>
<td>3000</td>
</tr>
<tr>
<td>6</td>
<td>Number of worse moves to decide in equation probability threshold (in turn to decide initial temperature $t_0$)</td>
<td>200</td>
</tr>
<tr>
<td>7</td>
<td>Initial temperature $t_0$</td>
<td>0.039</td>
</tr>
</tbody>
</table>
Image simulation Logic

Real Image → Optimization Function → Probability Calculation → Probability Checking
If Satisfied → Accept Image
If Not satisfied → Simulated Image adjustment
Simulated Image
Resources used

- **Study Area:**
  - Dehradun, Saharanpur (City & Periphery)

- **Satellite Images:**
  - Quick Bird
  - Temporal data used (March, May, December)

- **Software Used:**
  - Matlab (IP & Mapping Toolboxes)

- **Additional tools:**
  - Questionnaire Survey (Horticulture department)
  - Experts opinion (Simulated Annealing Parameters)
Field work

- **Survey details**
  - 10 sites surveyed
  - 50 trees measured
  - 2 areas (DDN, Saharanpur)
  - 3 arrangements (linear, sparse, regular)
  - Sampling scheme: stratified random

- **Field measurements**
  - Extent of tree
  - Tree Species
  - Approximate age
Programme Issues DEALT With

- High radiometric resolution of input image.
- Memory space optimisation during run.
- Code vectorisation used for faster calculations
- Flexible w.r.t input image & parameters
- Generic w.r.t. image resolution & size, number of objects, SA parameters
Programme Issues Dealt With

- Outputs as mat & xls files, graphs, in one single folder generated automatically, customized names based on parameters in a run
- Time performance profiles used to reduce time consuming processes
- Customized folder and file names
Results

Sparse arrangement

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Results

Linear arrangement
Results

Regular arrangement
Results

**Variograms in iterations**

- **Real Image**
- **Simulated Image**
- **Optimised Image**

Lag Distance h (meters) vs. Variogram value.
Results

![Behaviour of Fitness function](image.png)

**Behaviour of Fitness function**

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Evaluation of Results

- **Evaluation on:**
  - several images from two sites (DDN & Saharanpur),
  - different times (March, May & December),
  - Different species (Litchi & Mango Orchards)
  - 3 configurations (linear, regular & sparse)
  - varying number of objects.

- **Evaluation Methods:**
  - Visual analysis of patterns
  - Nearest Neighbour Index/Polygon pattern analysis

- **Evaluation stages:**
  - Binarisation
  - Image pattern matching
Research outcomes

- An algorithm for Spatial Simulated Annealing (developed, implemented and evaluated)
- Demonstrated potential use of variogram as an optimization function
- A flexible SA implementation w.r.t input images & SA parameters
- A generic SA implementation w.r.t image products, type of objects
- Outcome of a SA run reported as mat & xls files, figures & graphs
- Code optimization for performance w.r.t processing time and memory space
Potential Applications

- Pattern Recognition and matching
- Find images having clusters of similarly configured objects
- Content based image retrieval (CBIR)
- Get several choices for arrangements with similar spatial configuration (low object density) (think of example and put) - good for planners as a tool.
Potential Application Areas

- Image mining & CBIR
- Agro-forestry, Horticulture, Forestry
- Carbon budgeting/ sequestration studies
- Global warming & environmental pollution studies
- Planning & Management studies
Conclusion

- Usefulness of variogram as an optimization demonstrated
- Spatial Simulated Annealing implemented for image pattern matching
- Success of SA demonstrated on binarised images of individual trees for obtaining images with similar patterns.
- The methodology is put forward for further evaluation by application scientists and other researchers for its benefits.
Future recommendations/Further Work

- Extend for other type of objects of varying shapes.
- Extend for gray images
- Overlapping objects.
Thank You

Questions?

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Research Interest: Advanced Image Processing for information mining of geospatial data