Track 1.3
Understanding of Megacities

MACHINE LEARNING FOR BUILDING EXTRACTION AND INTEGRATION OF PARTICLE SWARM OPTIMIZATION WITH SLEUTH FOR URBAN GROWTH PATTERN VISUALIZATION FOR LIVABLE CITIES

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MEGACITIES

• 134% - Rate of Growth in number of megacities

• According to UN (United Nations), an Urban agglomeration with more than 10 million inhabitants is known as a megacity

• Megacities are a hub of business and catalyst to economic development

• This ever increasing and irreversible urban growth has given impetus to understand urban morphology in depth and its implications on surrounding nature
REASON FOR GROWTH

In Indian context the main reason for growth can be attributed to rural-urban migration due to the following factors

• Better Health facilities
• Job opportunities
• Improved living standards
KEY IMPACTS

• Environmental Deterioration
• Poor Infrastructure
• Increase in Urban Poor
• Vulnerable to Natural Calamities

Image Source: https://www.who.int
SUSTAINABLE GROWTH

1. Urban Growth Dynamics

2. Future Growth Potential

3. Suitable Policy Interventions
URBAN GROWTH MODELS

Artificial Life

Cellular Automata (CA)
Eg. SLEUTH

Agent Based Models (ABM)

Swarm Intelligence
Eg. ACO, BCO

Intelligent Stochastic Optimization Process

Genetic Algorithm (GA)
Eg. SLEUTH - GA

Simulated Annealing (SA)

Evolution Computing And Spatial DNA

Artificial Neural Network
ANN-CA

Spatial DNA

Knowledge Based Intelligent Systems

Fuzzy Logic
FZ-CA

Expert System

Heuristics Search

Reasoning System

Hybrid AI Systems

*Adapted from Wu and Silva, 2010.
SLEUTH – URBAN GROWTH MODEL

- SLEUTH is an acronym which stands for Slope, Land use, Exclusion, Urban, Transportation and Hillshade, its input layers
- The model, its documentation and source code have been **publicly available** making researchers to develop study based on their region
- SLEUTH is an outcome of Deltatron landuse model (DLM – CA-Mark) coupled with urban growth model (UGM -Boolean)
- Model depends on five growth coefficients and four growth rules

Image Source: http://gigalopolis.geog.ucsb.edu/
GROWTH RULES

- EDGE GROWTH
- SPONTANEOUS GROWTH
- NEW SPREADING GROWTH
- ROAD INFLUENCED GROWTH
ANALYSING EDGE GROWTH

• By default when a point (pixel) at the edge of the cluster grows, its attractiveness to grow on all directions are taken to be same.

• But in reality it varies from city to city.

• This study focused to build a probability matrix for the edge points neighborhood to predict the attractiveness for growth.

• Method was designed with a Particle-Swarm Optimizer (PSO) to optimize the way in which growth will occur.
**EXISTING**

- Picks a **Random** pixel on the neighborhood for urbanizing.

**IMPROVED**

- Introduce a **PSO** to optimize the selection of appropriate pixel

PSO will be included here.
PARTICLE SWARM OPTIMIZER

\[ V_{id}^{(t+1)} = WV_{id}^{(t)} + c_1 r_1 [p_{id} - x_{id}^{(t)}] + c_2 r_2 [p_{gd} - x_{id}^{(t)}] \]

\[ X_{id}^{(t+1)} = X_{id}^{(t)} + V_{id}^{(t+1)} \]

Image Source: https://www.hindawi.com/journals/ijap/2013/649049
https://en.wikipedia.org/wiki/Particle_swarm_optimization
STUDY AREA

KOLKATA, INDIA

- Popularly known as “The city of Joy”
- Located at the eastern part of India, the city is built on the banks of River Hooghly
- Metropolitan area: 1886 km²
- Population: 14,035,959 (2011)
- 3rd Biggest metro city in India
METHOD

Pre-Processing:
- Satellite Image Download
- Toposheets
  - Slope and Hillshade
  - Geo-registration and correction

Building Extraction:
- Extraction of study area: Crop
  - Generation of FCC
  - Pan Sharpening
  - Ground Truth Data
  - Google Earth Data

Land use and Land cover:
- Land cover analysis
  - NDVI
- Training data
  - Supervised Classification
  - Accuracy Assessment
  - Urban area extraction
    - Yes
    - Accuracy Assessment
    - Land use map and statistics
    - No
      - Training data accepted?

Output Maps and Result Interpretation

PSO-SLEUTH
METHOD

Flowchart Diagram:

1. **Start**
   - Parameters Initialization: Particle's position, velocity, and fitness
   - Generate first swarm (eight initial cells to be optimized)

2. **Evaluate fitness**
   - Record personal best position and fitness
   - Record global best position and fitness

3. **Swarms met termination criteria?**
   - Yes: End
   - No: Update particles

4. **Update position**
   - Update particles
   - Modify SLEUTH code based on optimized values

5. **Initial conditions and layer standardization**
   - Slope
   - Landline
   - Excluded
   - Urban
   - Transportation
   - Hillshade

6. **Test phase**
   - Image and Statistical output
   - Results satisfactory?
     - Yes: Calibration phase
     - No: Prediction phase

7. **Calibration phase**
   - Coarse
   - Fine

8. **Prediction phase**
   - Model fit measures
   - Log and average files
   - Image output
   - Time step (year): 1
BUILDING EXTRACTION

Total buffer area : 3638.49 sq. km

Coverage Area (%)

<table>
<thead>
<tr>
<th>Coverage</th>
<th>Area (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total area</td>
<td>100</td>
</tr>
<tr>
<td>Buildings</td>
<td>16</td>
</tr>
<tr>
<td>Non-buildings</td>
<td>84</td>
</tr>
</tbody>
</table>

Area analyzed : 15 sq.km

Closer view of the extracted buildings
RESULTS: LAND USE

- 181% increase in urban area in just 27 (1990-2017) years
- New settlements recognized along the transport corridors
- Increase in water bodies due to evolving aquaculture and pond ecosystem

<table>
<thead>
<tr>
<th>Year</th>
<th>Urban</th>
<th>Vegetation</th>
<th>Water</th>
<th>Others</th>
<th>Overall accuracy (%)</th>
<th>Kappa statistic</th>
</tr>
</thead>
<tbody>
<tr>
<td>1990</td>
<td>4.12</td>
<td>23.08</td>
<td>4.2</td>
<td>68.61</td>
<td>88</td>
<td>0.94</td>
</tr>
<tr>
<td>1999</td>
<td>6.45</td>
<td>21.17</td>
<td>4.7</td>
<td>67.68</td>
<td>93</td>
<td>0.96</td>
</tr>
<tr>
<td>2009</td>
<td>9.04</td>
<td>28.23</td>
<td>4.73</td>
<td>58</td>
<td>91</td>
<td>0.85</td>
</tr>
<tr>
<td>2017</td>
<td>11.58</td>
<td>22.18</td>
<td>6.24</td>
<td>60</td>
<td>91</td>
<td>0.89</td>
</tr>
</tbody>
</table>
SLEUTH MODEL - INPUTS
CALIBRATION RESULTS

Values out of 100

SLUETH coefficients

- Spread (64)
- Road Gravity (80)
- Breed (52)
- Diffusion
- Slope (16)

<table>
<thead>
<tr>
<th></th>
<th>NW</th>
<th>N</th>
<th>NE</th>
</tr>
</thead>
<tbody>
<tr>
<td>79</td>
<td>X</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>X</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>99</td>
<td>76</td>
<td>99</td>
<td></td>
</tr>
</tbody>
</table>

Legend:
- NW: North West
- N: North
- NE: North East
- W: West
- C: Centre
- E: East
- SW: South West
- S: South
- SE: South East
# PREDICTION RESULTS

<table>
<thead>
<tr>
<th>Fitness Statistic</th>
<th>BFM</th>
<th>PSO</th>
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</thead>
<tbody>
<tr>
<td>Product</td>
<td>0.0156</td>
<td>0.1758</td>
</tr>
<tr>
<td>Compare</td>
<td>0.6891</td>
<td>0.9889</td>
</tr>
<tr>
<td>Pop</td>
<td>0.9990</td>
<td>0.9947</td>
</tr>
<tr>
<td>Edges</td>
<td>0.8653</td>
<td>0.8763</td>
</tr>
<tr>
<td>Clusters</td>
<td>0.2061</td>
<td>0.9804</td>
</tr>
<tr>
<td>Size</td>
<td>0.6032</td>
<td>0.6543</td>
</tr>
<tr>
<td>Leesalee</td>
<td>0.5192</td>
<td>0.4507</td>
</tr>
<tr>
<td>Slope</td>
<td>0.9957</td>
<td>0.9993</td>
</tr>
<tr>
<td>% Urban</td>
<td>0.9950</td>
<td>0.9992</td>
</tr>
<tr>
<td>Xmean</td>
<td>0.6951</td>
<td>0.7123</td>
</tr>
<tr>
<td>Ymean</td>
<td>0.5896</td>
<td>0.9984</td>
</tr>
<tr>
<td>Rad</td>
<td>0.9998</td>
<td>0.9948</td>
</tr>
<tr>
<td>OSM</td>
<td>0.050</td>
<td>0.660</td>
</tr>
</tbody>
</table>
RESULTS: PSO-SLEUTH

- Output from SLEUTH-PSO model suggested KMDA will have at least 757.91 km$^2$ of urban land use by the year 2025
- This is a 53% increment from 2017, alarming sign for planners and administrators

Analyzing SLUETH coefficients

- High – Road Gravity(80)
  High values of road gravity reflect road acting as key urbanization factor
- Medium – Breed(52), Spread(64)
  Signifies the influence of breeding a new urban site in the periphery or spreading type of urban growth from already existing core urban area, can also be referred to as sprawling at the outskirts
- Low – Diffusion(8), Slope Resistance(16)
CONCLUSION

- Land use results show rapid increase in urban areas during last two decades motivates to predict future land use pattern change.
- The prediction results of SLEUTH-PSO model is better than traditional SLEUTH model (Brute Force Method).
- In this case, the prediction accuracy is increased by almost 12 times.
- SLEUTH-PSO made significant improvements in predicting the spatial extent of the city.
- Statistics and findings insists planners and concerned government officials to focus on sustainable urban growth concepts.
SELECT REFERENCES

THE BEST WAY TO PREDICT FUTURE IS TO CREATE IT.
- PETER DUCKER

THANK YOU