Distributed Evolutionary Design

Island-Model Based Optimization of Steel Skeleton Structures in Tall Buildings

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Outline

- Motivation
- Distributed Evolutionary Algorithms
- Inventor 2003
- Evolutionary Design of Steel Structural Systems in Tall Buildings
- Experimental Results
- Conclusions
Motivation

- Increased complexity of design problems
- Increased computational effort to evaluate designs

but...

- Cost of computation continues to decrease
- Various parallel computation architectures available
Distributed Evolutionary Algorithms

- Population of Independent Solutions = Opportunity for Applying Parallel Computation Architectures

- 3 major approaches:
  - Coarsely-grained “island” models
  - Finely-grained “diffusion” models
  - Agent-oriented models

- Two objectives:
  - Speed improvements
  - Problem solving improvements (fitness)
Inventor 2003

- An integrated design support tool
- Implements multi-population evolutionary computation (island model)
- Uses Java spaces technology
- Distributes time-expensive evaluations through a network
Evolutionary Design of Steel Structural Systems in Tall Buildings

- Topological optimum design problem
- Planar transverse designs of steel skeleton structures in tall buildings
  - 3-bay structures
  - 36 stories
  - 7 types of bracings
  - 2 types of beams
  - 2 types of supports
Design Representation

- **Wind bracings:**
  - No bracing
  - Diagonal bracing / diagonal bracing \ (a)
  - K bracing
  - V bracing
  - Simple X bracing
  - X bracing

- **Beams and supports**
  - Pinned beam
  - Fixed beam
  - Pinned support
  - Fixed support
Experiments - Design

- Initial experiments conducted with island models with four subpopulations
- Each subpopulation was of equal size and evolved by the same EA
- Two connectivity topologies (migration strategies) were investigated:
  - Ring
  - Fully-connected
Experiments – Problem Parameters

- number of bays: 3
- number of stories: 36
- bay width: 20 feet (6.01 m)
- story height: 14 feet (4.27 m)
- Distance between transverse systems: 20 feet (6.01 m)
- Structural analysis method: first-order
- Serviceability conditions: H/600
- Types of initialization: Random, set of 12 feasible designs
## Experiments – EC Parameters

### Island-model EA parameters:

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of subpopulations</td>
<td>4</td>
</tr>
<tr>
<td>Size of the populations</td>
<td>Uniform</td>
</tr>
<tr>
<td>Type of local EA</td>
<td>Uniform</td>
</tr>
<tr>
<td>Connectivity topology</td>
<td>Ring, fully connected</td>
</tr>
<tr>
<td>Migration mechanism</td>
<td></td>
</tr>
<tr>
<td>- How often migrations occur</td>
<td>Every 10 generations</td>
</tr>
<tr>
<td>- Which individuals migrate</td>
<td>Best individual replaces a random one in a subpopulation</td>
</tr>
</tbody>
</table>

### Local EA parameters:

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>EA</td>
<td>ES</td>
</tr>
<tr>
<td>Pop. sizes (parent, offspring)</td>
<td>(3,15)</td>
</tr>
<tr>
<td>Generational model</td>
<td>Overlapping</td>
</tr>
<tr>
<td>Selection (parent, survival)</td>
<td>(uniform stochastic, truncation)</td>
</tr>
<tr>
<td>Mutation rate</td>
<td>0.05</td>
</tr>
<tr>
<td>Crossover (type, rate)</td>
<td>(uniform, 0.2)</td>
</tr>
<tr>
<td>Fitness</td>
<td>Weight of the steel structure (minimization problem)</td>
</tr>
<tr>
<td>Initialization method</td>
<td>Random, arbitrarily selected initial parents (see section 4.1)</td>
</tr>
<tr>
<td>Constraint handling method</td>
<td>Death penalty (infeasible designs assigned 0 fitness)</td>
</tr>
</tbody>
</table>

### Simulation parameters:

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Termination criterion</td>
<td>100 generations (for each subpopulation)</td>
</tr>
<tr>
<td>Number of runs</td>
<td>5 (in each experiment)</td>
</tr>
</tbody>
</table>
Experimental Results

- High sensitivity of results to the quality of initial designs
Experimental Results

- Convergence rates highly dependent on the connectivity topology
Experimental Results

- Random initialization provides a sustained evolutionary design progress
Conclusions

- Only preliminary results reported
- Experiments revealed feasibility of distributed EA in structural design
- This approach is more computationally complicated, but:
  - It allows the exchange of good genetic material and thus improves the quality of designs in terms of fitness
  - Distributed EA with random initialization provide sustained evolutionary design progress and ability to escape local optima