Pearl Hunter: An Inspired Hyper-heuristic

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Outline

1. Pearl Hunting
2. The Pearl Hunter
3. Training and Validation on HyFlex
4. Conclusions
Pearl Diving

- *Pearl diving* is an out-of-date diving activity of retrieving pearls from oysters.

- Can still be found in:
  - Some Asian tourist sites,
  - Virtual games.

In Australia (screenshot of “Introduction to pearls and Australian Pearl Divers”, © by Australian Opal Cutter [youtube.com/watch?v=V6vu8yglndw](https://www.youtube.com/watch?v=V6vu8yglndw))

In Qatar (screenshot of “Pearling”, © Qatar Pavilion, World EXPO 2010)
Pearl Diving and Simulation

- In a search perspective, pearl hunting consists of repeated
  - *diversification* (surface and change target area)
  - *intensification* (dive and find pearl oysters).
- In the paradigm of Iterated Local Search (Lourenço et al, 2003).
- Simulated operations
  - *move* (*diversification*, 1 source or multiple sources)
  - *dive* (*intensification*)
    - *snorkeling* (quick, low level local search, stops after any improvements)
    - *deep dive* (scuba; slow, high level local search, till no further improvements)
### Correlations Between Snorkeling and Deep Dive

Table 1: Pearson correlations between improvements by snorkeling (10% maximum depth of search) and deep dive (maximum depth of search) in 3 domains of CHeSC

<table>
<thead>
<tr>
<th>Diversification by LLH</th>
<th>Max-SAT</th>
<th>Bin Packing</th>
<th>Flow Shop</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Crossover</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pearson Cor.</td>
<td>0.82*</td>
<td>0.47^</td>
<td>0.88*</td>
</tr>
<tr>
<td>Sig. (2-tailed)</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
</tr>
<tr>
<td>N</td>
<td>466</td>
<td>143</td>
<td>317</td>
</tr>
<tr>
<td><strong>Mutation</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pearson Cor.</td>
<td>0.61^</td>
<td>0.11</td>
<td>0.83*</td>
</tr>
<tr>
<td>Sig. (2-tailed)</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
</tr>
<tr>
<td>N</td>
<td>112</td>
<td>1405</td>
<td>752</td>
</tr>
<tr>
<td><strong>Ruin-recreate</strong> (extra)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pearson Cor.</td>
<td>0.08</td>
<td>0.07</td>
<td>0.58^</td>
</tr>
<tr>
<td>Sig. (2-tailed)</td>
<td>0.51</td>
<td>0.11</td>
<td>0.00</td>
</tr>
<tr>
<td>N</td>
<td>70</td>
<td>551</td>
<td>328</td>
</tr>
</tbody>
</table>

#### Correlations:

- ✧ Strong (*) or moderate (^) positive coefficient with a significant level 0.01
- ✧ $1 \leq \frac{N_{\text{snorkeling}}}{N_{\text{deepdive}}} \leq 10$, choose best of snorkeling in practice
Pearl Hunter: A Hyper-heuristic Imitation

“Environment”:
- *Shallow water*, where deep dive always returns the same as snorkeling
- *Sea trench*, where deep dives cost too much time at maximum depth-of-search
- *Default, otherwise*

Preparation of Low Level Heuristics (LLHs)
- Selective scheme (CHeSC2011)
  - Choose \( \{A, B\} \) from \( \{A, B, C\} \)
- Constructive scheme
  - Pre-trained
  - Online trained
Pearl Hunter

- Pearl Hunter can drop a *Buoy* at the depth of first deep dive, to escape from local optimum by mutations (SIs).
- Four running modes (portfolios) of selected LLHs:
  - **A**: all moves averagely, with a *Buoy* mark
  - **B**: *crossover* with a *Buoy* mark (triggering a few mutations)
  - **C**: *crossover* only, no mutation, no *Buoy*
  - **D**: Sea trench mode, all surface moves averagely, no *Buoy*

Moves are subject to online pruning.

- Other tricks:
  - tabu lists (memory), “mission restarts” (go to new areas)
HyFlex and CHeSC

- HyFlex (Hyper-heuristics Flexible framework) is a java cross-domain platform (Burke et al, 2011)
  - 6 domains, 4 public (training domain) and 2 hidden
  - “Black-box” low-level heuristics in 4 categories:
    ✗ Crossover, Mutation, Ruin-recreate, and Local search
  - Parameters to control low-level heuristics:
    ✗ “Intensity” of mutations, and “depth of local search”


- Pearl Hunter was ranked in CHeSC:
  ✗ 4th out of 20 entries overall,
  ✗ 1st out of 20 entries in the hidden domains.
HyFlex and CHesc: BF-Tree Obtained by Offline Learning (by Weka v3.5)

- $D_{\text{murr}}$: Depth of the mission in the Mutation and Ruin-recreate test,
- $M_{\text{co}}$: Number of missions completed in the Crossover test,
- $N$: Number of sub-optimal solutions found in total,
- $P_{\text{dir}}$: Percent of sub-optimal solutions found right after some moves (before any dive),
- $P_{\text{mu}}$: Percent of sub-optimal solutions found in iterations started with Mutation moves,
- $P_{\text{rr}}$: Percent of sub-optimal solutions found in iterations started with Ruin-recreate moves,
Tests on Personnel Scheduling: Beyond the 600s Time Limit of CHeSC

- On large-scale personnel scheduling problems,
  - Running time was increased to 10 hours (normalized to P4 3GHz),
  - Same decision tree and algorithm codes

- New best known solutions:

<table>
<thead>
<tr>
<th>Instance</th>
<th>Men</th>
<th>days</th>
<th>Time (h)</th>
<th>Result</th>
<th>Prev BK*</th>
<th>% improved</th>
</tr>
</thead>
<tbody>
<tr>
<td>CHILD-2A</td>
<td>41</td>
<td>42</td>
<td>10</td>
<td>1,095</td>
<td>1,111</td>
<td>1.4</td>
</tr>
<tr>
<td>ERRVH-A</td>
<td>51</td>
<td>42</td>
<td>10</td>
<td>2,142</td>
<td>2,197</td>
<td>2.5</td>
</tr>
<tr>
<td>ERRVH-B</td>
<td>51</td>
<td>42</td>
<td>10</td>
<td>3,121</td>
<td>6,859</td>
<td>54.5</td>
</tr>
</tbody>
</table>

* Best known values were collected from [http://www.cs.nott.ac.uk/~tec/NRP/misc/NRP_Results.xls](http://www.cs.nott.ac.uk/~tec/NRP/misc/NRP_Results.xls)

- A possible reason
  - A new “vertical” swap concept first implemented in low-level heuristics on HyFlex
Conclusion

- We present a hyper-heuristic
  - Imitates pearl hunting
  - Perceives “environment” of search
  - Determines a perturbation mode by offline learning
  - Generates different modes of ILS

- We find the results of tests encouraging

- Possible future works
  - Hunters can generate new LLHs besides a selection
References

Thank you for your attention!

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