Concurrent Genetic Algorithm with Island Migration

Markus Solbach

Laboratory for Active and Attentive Vision
Department of Computer Science and Engineering
York University, Toronto, Ontario, Canada

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Overview

- The Paper
- Genetic Algorithm
- Island Migration
- Test-Domain
- Conclusion

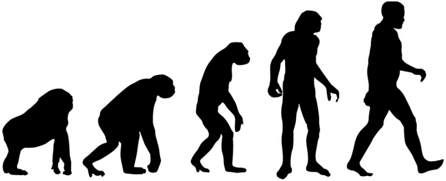


Figure :Evolution ||*i.livescience.com (Oct. 5. 15)*

The Paper

- Worthy N Martin, Jens Lienig, and James P Cohoon. Island (migration) models: evolutionary algorithms based on punctuated equilibria.
  Handbook of evolutionary computation, 6(3), 1997.

Figure :
Worthy N. Martin
||*cs.virginia.edu (Oct. 7. 15)*

Figure :
Jens Lienig
||*www.ifte.de (Oct. 7. 15)*

Figure :
James P. Cohoon
||*cs.virginia.edu (Oct. 7. 15)*

Genetic Algorithm

Genetic Algorithm

- Genetic Algorithm
  - evolutionary algorithm
  - population-based optimization algorithm
  - meta heuristic optimization algorithm
  - problems without an analytic approach
  - follows biological evolution (C. Darwin)
  - relies heavily on randomization

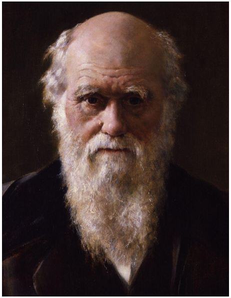


Figure : Charles Robert Darwin (1809-1882)
|| *wikipedia (Oct. 5. 15)*

Real Word Example

- X-Band Antenna Design
  - NASA's Space Technology 5 Spacecraft
  - Automatically designed
  - changes: minimal effort of human effort

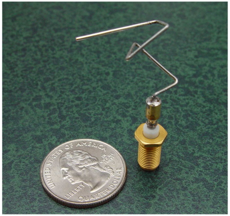
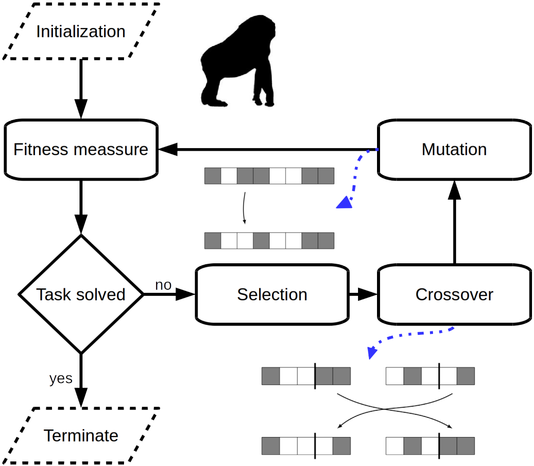


Figure : Evolved Antenna ST5-33.142.7
||*wikipedia (Oct. 5. 15)*

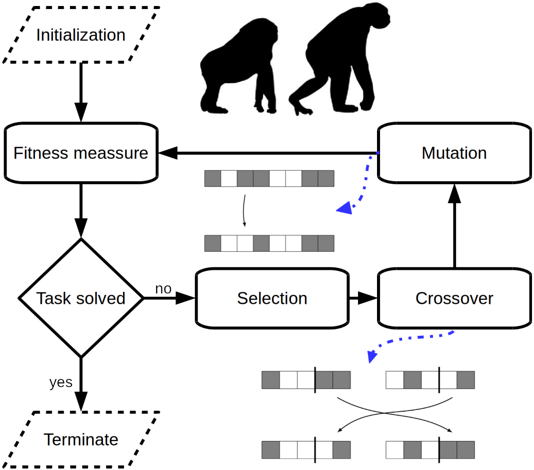
Genetic Algorithm Flow Chart

Generation 0



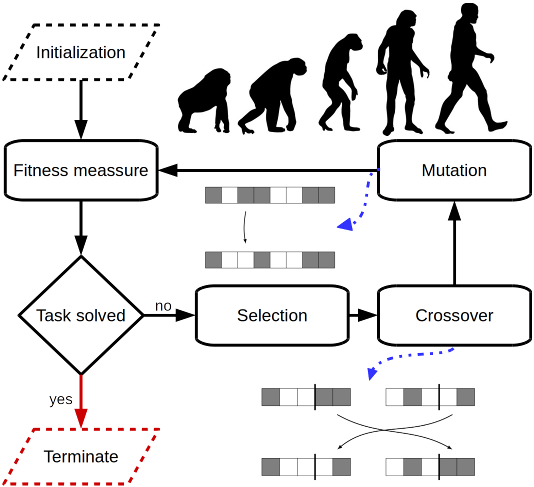
Genetic Algorithm Flow Chart

Generation n



Genetic Algorithm Flow Chart

Generation $n + m$



Population-based optimization algorithm

- Search-space usually very big
- Each individual is a solution candidate
- Search-space affects population
  - small search-space = small population
  - ... and vice versa
- Size of population affects **run-time**
- **Local Maxima Problem**

Figure : Example Population

Island Migration

Extension: Island Migration

- Isolated Evolution
- Each Island is a subpopulation
- Independent GA on each Island
- Migration after an epoch e
- **Enrich Gen-Pool**

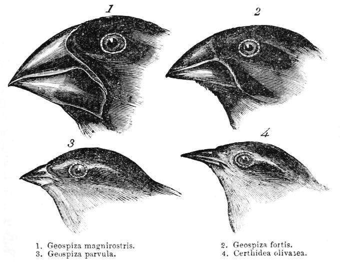
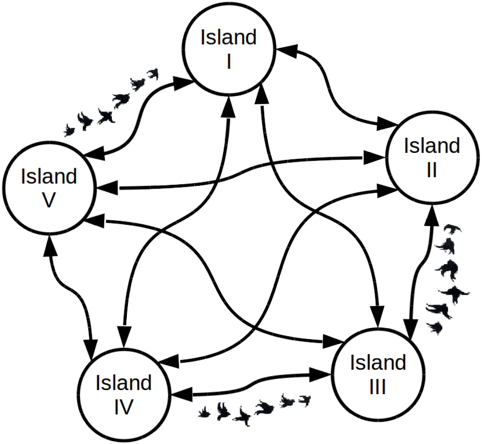


Figure :
Darwin's Finches ||*wikipedia (Oct. 7. 15)*

Island Migration Illustration



Island Migration Parameters

- Epoch length?
- Dynamic Migration?
  - How to set Threshold?
  - How often?
- How many Individuals will migrate?
- Which Individuals?
- How Islands are connected?
- *"Different Fitness functions?"*
- ...
- $GA\ Param. + IM\ Param. > 10$

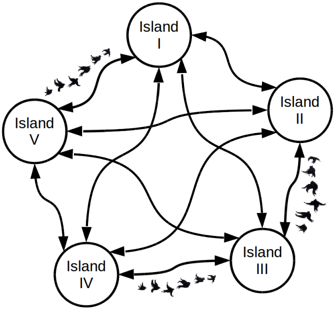


Figure : Island Migration Illustration

GA Param - Rate: Mutation, Crossover. Number of Individuals and Generations, fitness-threshold, ...

Test-Domain

VLSI design problem

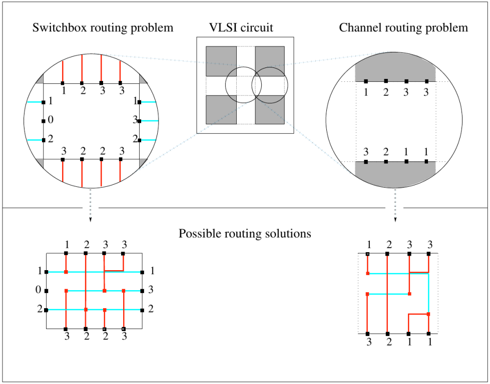


Figure :Example VLSI problem ||*source* : [1]

[1] W. Martin, J. Lienig, and J. Cohoon. Island (migration) models: evolutionary algorithms based on punctuated equilibria. *Handbook of evolutionary computation*, 6(3), 1997.

VLSI design problem

Important Factors

- Crosstalk (coupled capacitance)
- Propagation delay (length of interconnections)
- Number vias (electrical and fabrication problems)

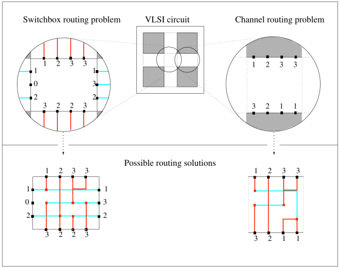


Figure :Example VLSI problem

Fitness-Function of Individual p_i

$$Obj(p_i) = w_1 \cdot l_{nets}(p_i) + w_2 \cdot n_{vias}(p_i) + w_3 \cdot l_{par}(p_i) \quad (1)$$

Where:

- $l_{nets}(p_i)$ total length of nets of p_i
- $n_{vias}(p_i)$ number of vias of p_i
- $l_{par}(p_i)$ total length of crosstalk segments of p_i
- w_1 weight factor (empirically set to 1.0)
- w_2 weight factor (empirically set to 2.0)
- w_3 weight factor (empirically set to 0.01)

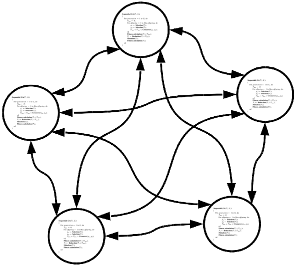
Actually an inverse Fitness-Function

- High Value $\hookrightarrow$ Bad Fitness $\|$ *Low Value* $\hookrightarrow$ Good Fitness

Pseudocode

Each Island/Thread $\hookrightarrow$ One Sequential Genetic Algorithm

Sequential_GA($\mathcal{P}_i$, G_i)
{
For *generation* $\leftarrow 1$ to G_i do
$\mathcal{P}_{\text{new}} \leftarrow \emptyset$;
For *offspring* $\leftarrow 1$ to $Max\_offspring_i$ do
$p_\alpha \leftarrow$ **Selection**($\mathcal{P}_i$);
$p_\beta \leftarrow$ **Selection**($\mathcal{P}_i$);
$\mathcal{P}_{\text{new}} = \mathcal{P}_{\text{new}} \cup$ **Crossover**(p_α, p_β);
od
Fitness_calculation($\mathcal{P}_i \cup \mathcal{P}_{\text{new}}$);
$\mathcal{P}_i \leftarrow$ **Reduction**($\mathcal{P}_i \cup \mathcal{P}_{\text{new}}$);
Mutation($\mathcal{P}_i$);
Fitness_calculation($\mathcal{P}_i$);
od
}



Conclusion

Conclusion

- A promising extension to GA is given
  - Usage of Concurrency (Run-Time)
  - Bigger Gen-Pool (Local Maxima Problem)
- Test-Domain seems to be well chosen (Huge Search-Space)

Plan

- Implement both algorithms (Sequential and Island Migration)
- Compare performances of both (Best Fitness and Run-Time)
- Compare to other routing algorithms (WEAVER, Monreale,...)

Challenges

- Implementation details very sparse (9 Islands each 50 Individuals)
- Shared memory access (migration)

Benchmark

- 11 Benchmarks with published results available
- *Joo6_16*
  - WEAVER *hookrightarrow* 220 s, 23 Vias, 131 Net-length
  - Monreale *hookrightarrow* ? s, 19 Vias, 120 Net-length
  - GAP[2] *hookrightarrow* **207** s, **15** Vias, **115** Net-length
- *Burstein's Difficult Channel*
  - PACKER *hookrightarrow* 87 s, 10 Vias, 82 Net-length
  - Monreale *hookrightarrow* ? s, 10 Vias, 82 Net-length
  - GAP[3] *hookrightarrow* **16** s, **8** Vias, 82 Net-length

[2] Another Genetic Algorithm
[3] Another Genetic Algorithm

Real Word Example

- X-Band Antenna Design
  - NASA's Space Technology 5 Spacecraft
  - Automatically designed
  - changes: minimal effort of human effort
  - $F = vswr \cdot gain \cdot standarddeviation$

[4]

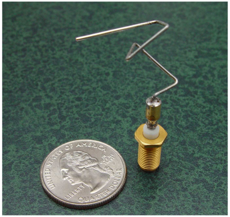


Figure : Evolved Antenna ST5-33.142.7 || *wikipedia (Oct. 5. 15)*

[4] $vswr$ = standing wave ratio