CoEvolving Memetic Algorithms (COMA) A framework for algorithm creation and adaptation

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Overview

- Memetic Algorithms in a broader context
- What do I mean by memes ?
- Co-evolving Gene and Memes
  - COMA framework
  - Key findings and open questions
- Conclusions

Positioning

Adaptive Search – but to what?

- An instance of a problem?
  - Algorithm Selection Problem (ML) / NELLI
- A history of search on an instance?
  - Adaptive Operator Selection (meta-heuristics)
  - Hyper-heuristics / VNS etc.
- Distinct regions of search space?
  - Self-Adaptation (meta-heuristics)
  - (some) Multimeme Algorithms

Memetic algorithms as adaptive systems

- Typical Viewpoint: MA = EA +Local Search
- Get better results with multiple LS operators
  - (Krasnogor & Smith, Gecco '01 ->, Ong & Keane '04 IEEE TEC)
  - Blurred distinction to Hyper-Heuristics
- Adaptive MAs (Ong et al. 2006 IEEE SMC-B)
  - as a more general framework
  - AMA = Meta-heuristic + set of LS +choice function

Ong et al.'s classification

Source of information
To adaptation mechanism

Nature of adaptation mechanism

Adaptive Type		Adaptive Level		
		External	*Local*	*Global*
Static		Basic meta-Lamarckian learning / Simplerandom		
Adaptive	*Qualitative Adaptation*		Randomdescent / Randompermdescent	Tabu-search
	Quantitative Adaptation		Sub-Problem Decomposition/ Greedy	Straightchoice/ Rankedchoice/ Roulettechoice/ Decompchoice/ Biased Roulette Wheel
Self-Adaptive			Multi-memes/ Co-evolution MA	

Meuth *et al.* categorisation of MAs

- **First Generation**:
  - Global search paired with local search
- **Second Generation:**
  - Global search with multiple local optimizers.
  - Memetic information (Choice of optimizer) passed to offspring (Lamarckian evolution)
- **Third Generation:**
  - Global search with multiple local optimizers.
  - Memetic information (Choice of local optimizer) passed to offspring (Lamarckian Evolution).
  - A mapping between evolutionary trajectory and choice of local optimizer is learned
- **Fourth Generation**:
  - Mechanisms of recognition, generalization, optimization, and memory are utilized *to search meme space*

R. Meuth, M. Lim, Y. Ong, and D. Wunsch, "A proposition on memes and meta-memes in computing for higher-order learning," *Memetic Computing*, vol. 1, no. 2, pp. 85–100, 2009.

How do we classify Meme Transmission?

With respect to the:

1. Search space?
   - Global /local –depends on move operator/distance metric
   - Y.-S. Ong, M. H. Lim, N. Zhu, and K.-W. Wong, "Classification of adaptive memetic algorithms: a comparative study," *IEEE Trans. Systems, Man, and Cybernetics,B:* 36(1) 141–152, 2006.
2. Individual choosing a meme?
   - Credit assignment problem
   - J. E. Smith, "Estimating meme fitness in adaptive memetic algorithms for combinatorial problems," *Evolutionary Computation*, 20 (2) 165-188, 2012.
3. Memepool?
   - Social theories (Vertical/horizontal/diagonal)
   - N. Krasnogor and J. E. Smith, "Emergence of Profitable Search Strategies Based on a Simple Inheritance Mechanism, GECCO-2001, pp. 432–439.

Or more generally…

AMA = population of solutions
+ population of memes

- Both adapted by meta-heuristics,
- Individual's behavioural responses can be modified by memes
  - Could think of as individual or social learning
- But why not also teaching?
- Or task sharing more generally?

Co-Evolving Memetic algorithms

Generative H-H

"Perturbative" rather than constructive.

- Framework for investigating meme-gene co-adaptation from 1-4G
- Separate populations of genes and memes
- Run a search algorithm in each space,
- Could use any representation and model, needn't be EAs
  - For example Nogueras and Cottas use EDAs

CO

- Me
  -
- Set
- Giv
  -
  - 2
- Evolved memes capture underlying problem structure
  - E.g., solve concatenated trap functions in linear time,
  - "rediscover" Protein folding rules
- Changing LS neighbourhoods facilitate escape from local optima

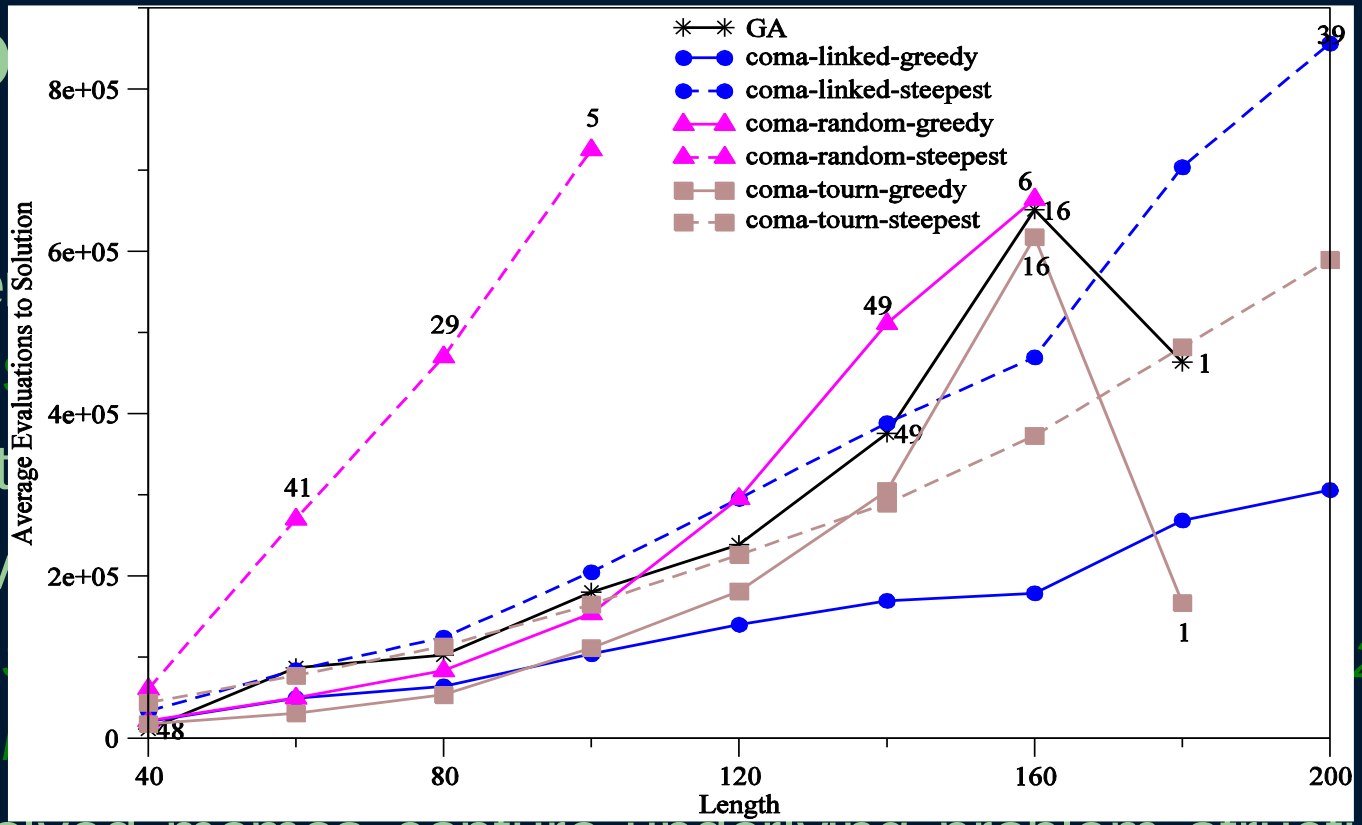
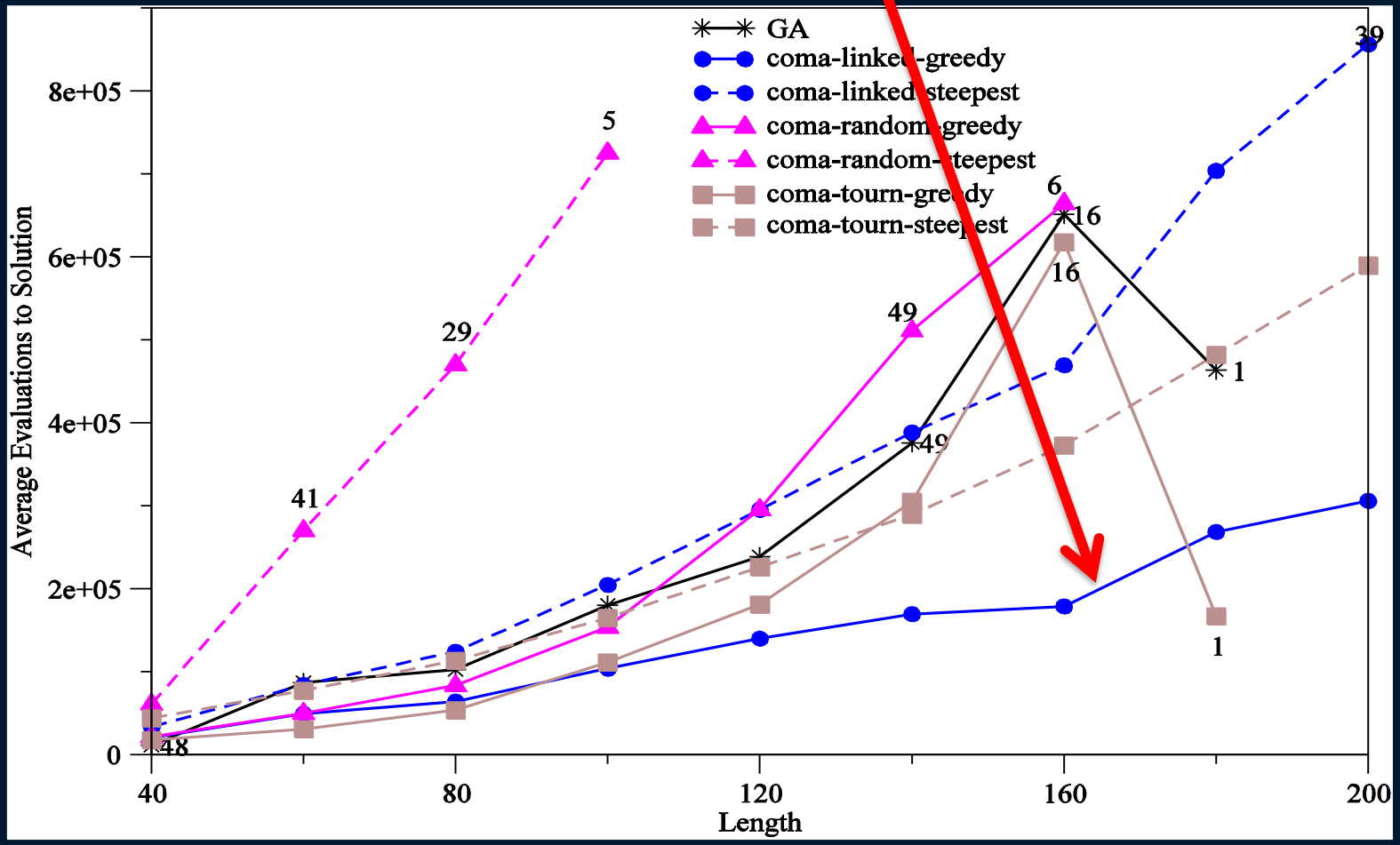


Illustration: 4 trap problem

Linear with $R^2 > 0.8$



Population of evolving solutions

r d d l u l u u r u r d r d r d d l u
u l d l u l u u r u u l u l u r l l u
u r l l u l u u r u u l u l u r l l u
r d d l u l l u r u r d r d r d d l u
u r r l u l l u r u r d r d r d d l u

- This example from protein structure prediction
- Offspring created by normal processes of selection, crossover and mutation

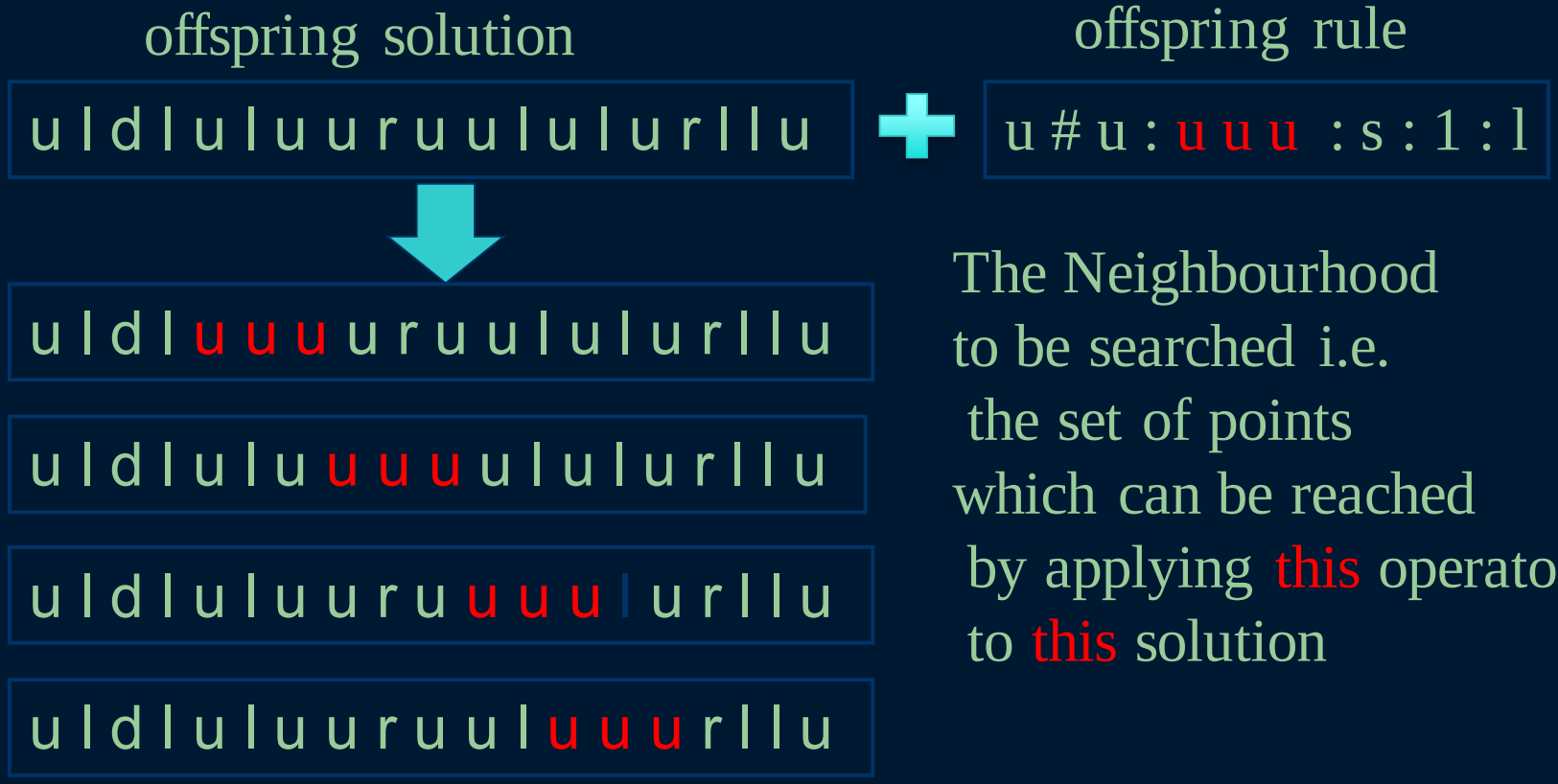
Population of Rules

Condition	Action	Pivot	Depth	Linkage
r # l u#r	r u l d u l	S	1	L
# # # r	r r u u	G	2	R
l # r	l r d	S	-1	L
l l # d	l r u u	G	2	F
# # u u #	# # u r r	S	3	L

- Linkage indicates gene-meme pairing

  Self-adaptive linkage, Random, Fitness based
- Pivot : *Steepest / Greedy search of neighbourhood.*
- Depth: *-1 indicates search to local optima.*

One application



The Neighbourhood to be searched i.e. the set of points which can be reached by applying this operator to this solution

Some key results

- Different spaces need different search algorithms:
  - Obvious if the encoding is very different, but also true if the same
  - e.g. Nogueras & Cotta showed Laplacian correction to maintain entropy was useful in solution but not meme space
- The credit assignment issue differs between spaces
  - Solutions: Maturana et al showed **extreme** reward gave best results for operator adaptation in solution space (IEEE CEC'09)
  - Memes: **mean** reward is better for various 2G and 4G strategies
  - Best results: **local** adaptation using piecewise linear fitness
- Ideas can overwhelm geography
  - More rapid dispersion in meme space can reduce effects of deme separation in gene space

Some open questions

- Rate of adaptation:
  - So far work has used synchronous adaption of memes,
  - is this necessary or desirable?
- Richer transformations?
  - Extend the regular expressions used for rewriting
  - Or use GP (cf. Fukunaga ECJ 2002 did it offline),
  - Simoes et al (PPSN14) self-adapted neural transformations (effectively endosymbiotic memes),
- Extension to modelling problems
  - Memes for genetic improvement of software?
- Memes for teaching as well as learning?

And more: How does all this work within the context of

- Dynamic Optimisation/Modelling
  - What is needed for continuous adaptation
- Interactive Machine Learning / Optimisation
  - Longer term adaption/selection of memes according to human behaviour and reactions
  - Being explored with IPAT tool
    - Allows interaction with anything that can be shown/heard/watched via HTML5
    - Shortly to be available as open source framework
- Expensive problems that need surrogate models
  - How approximate can you get and still adapt?

Conclusions

- COMA framework support research into the co-adaption of problem solving strategies with the solutions to the problem being solved.
  - So closely linked with Hyperheuristics etc.
- Premise: even for simple problems the optimal strategies will vary during search
  - So online adaptation methods are necessary
  - And may not be designable in advance
- Available on request as C libraries, welcome ports to other languages

What more might we be able to get?