

Research review: a modified micro genetic algorithm for undertaking multi-objective optimization problems

URL	http://weko.wou.edu.my/?action=repository_uri&item_id=498
-----	---



Research Review

A Modified micro Genetic Algorithm for undertaking Multi-Objective Optimization Problems

Tan Choo Jun

School of Science and Technology

November 2014

Preliminaries

Motivation

Preliminaries

Research Problem & Objective

Literature Review

The MmGA Model

Conclusions and Contributions

Future Works

Real-world problems often entail multiple and yet conflicting objectives, known as **Multi-objective Optimization Problems (MOPs)**



An example of the typical cost-profit trade-off and the Pareto front.

Pareto non-dominated solutions:

An optimization phenomenon whereby it is impossible to make any one solution better off without causing at least one solution worse off

Preliminaries

Motivation

Preliminaries

Research Problem & Objective

Literature Review

The MmGA Model

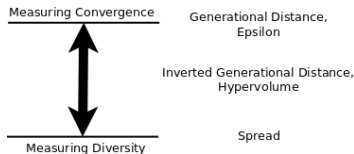
Conclusions and Contributions

Future Works

Why using **Evolutionary Algorithm** (EA)?

- EAs are useful for tackling optimization problems by exploiting natural selection phenomena and the learning capability of problem solving

Pareto optimality principle is used to measure the effectiveness of **Multi-Objective Evolutionary Algorithms** (MOEAs) using MOP indicators as follows:



A classification of MOP indicators

Preliminaries

Research Focus

Preliminaries

Research Problem & Objective

Literature Review

The MmGA Model

Conclusions and Contributions

Future Works

- This research focuses on tackling MOPs using MOEA-based model.
- Specifically, the **micro Genetic Algorithm** (mGA) is used as the base MOEA model, which has salient properties as follows.
 - a Genetic Algorithm (GA) evolves with a small population size, i.e. three to six chromosomes
 - able to solve non-linear optimization problems
 - uses a restart strategy to achieve convergence and to maintain diversity as compared with GA

Preliminaries

Research Focus

Preliminaries

Research
Problem &
Objective

Literature
Review

The MmGA
Model

Conclusions and
Contributions

Future Works

- mGA is used as the building block to design and develop an enhanced model to tackle MOPs, i.e. **Modified mGA** (MmGA)
- The MmGA is evaluated comprehensively using benchmark MOPs

Preliminaries

Research Problem & Objective

Preliminaries

Research Problem & Objective

Literature Review

The MmGA Model

Conclusions and Contributions

Future Works

The key research questions is:

- how to improve the convergence properties of the MmGA solutions towards the Pareto front while preserving the salient properties of the original mGA model?

The research objectives is:

- to improve the original mGA model in tackling MOPs with good convergence properties towards the Pareto front

Literature Review

Categories of MOEAs

Preliminaries

Research
Problem &
Objective

Literature
Review

The MmGA
Model

Conclusions and
Contributions

Future Works

MOEA Category	Usage
Decomposition-based	Novel MOEA design and formation (Li and Zhang, 2009; Ke et al., 2013), and arc routing problem (Mei et al., 2011a).
Preference-based	Novel MOEA design and formation (Thiele et al., 2009; Liu, Wang, Liu, Fang and Jiao, 2013; Wagner and Trautmann, 2010).
Indicator-based	Novel MOEA design and formation (Wagner and Trautmann, 2010; Bader and Zitzler, 2011), and nurse scheduling (Basseur et al., 2012).
Hybrid-based	Novel MOEA design and formation (Elhossini et al., 2010; Yang et al., 2009), vehicle routing problem (Cattaruzza et al., 2013), arc routing problem (Liu, Jiang and Geng, 2013), and traveling salesperson problem (Castro et al., 2013).
Memetic-based	Novel MOEA design and formation (Soliman et al., 2009; Fernandez Caballero et al., 2010), arc routing problem (Mei et al., 2011b), environmental power unit commitment design (Li, Pedroni and Zio, 2013), permutation flow shop scheduling (Chiang et al., 2011), job shop scheduling (Frutos and Tohmé, 2013).
Co-evolution-based	Novel MOEA design and formation (Soliman et al., 2009; Wang et al., 2013), ship design (Cui and Turan, 2010), knapsack problem (Jiao et al., 2013).

Literature Review

mGA-based models

Preliminaries

Research Problem & Objective

Literature Review

The MmGA Model

Conclusions and Contributions

Future Works

Year	Model	Characteristics and Usage
2001, 2005	mGA (Coello and Pulido, 2001, 2005)	Original mGA implementation for undertaking benchmark MOPs.
2003	mGA2 with an adaptive parameter tuning mechanism (Toscano Pulido and Coello, 2003)	An extended mGA (Coello and Pulido, 2001) for undertaking benchmark MOPs.
2007	mGA with Newton-Raphson load flow algorithm (Mendoza et al., 2007)	A model used to optimize localization of AVR's.
2009	mGA with novel encoding and genetic operators (Mendoza et al., 2009)	A model used to optimize power losses and reliability indices in a power distribution system.
2011	mGA with a fuzzy controller (Chen, 2011)	A model used to optimize parameters of a fuzzy controller for vehicle suspension control design.

The population sizes in mGA-based models

SOP	{	Size 5:	Krishnakumar (1990), Johnson and Abushagur (1995), Smajic et al. (2009), Watanabe et al. (2010), Itoh et al. (2012)
		Size 6:	Chu et al. (2013)
		Size 7:	Ali and Ramaswamy (2009)
MOP	{	Size 3, 5:	Mendoza et al. (2007)
		Size 4:	Coello and Pulido (2001); Coello and Toscano Pulido (2001); Coello and Pulido (2005), Toscano Pulido and Coello (2003)
		Size 5:	Mendoza et al. (2009)
		Size 6:	Chen (2011)

The MmGA Model

Preliminaries

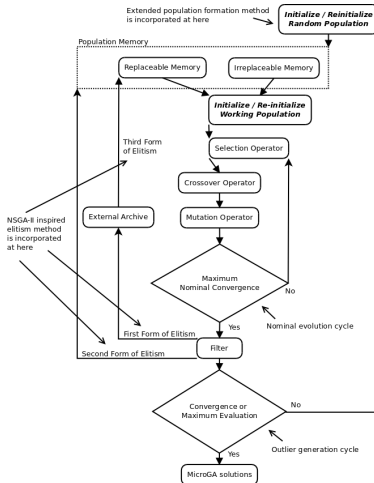
Research Problem & Objective

Literature Review

The MmGA Model

Conclusions and Contributions

Future Works



A flowchart of the proposed MmGA model.

The MmGA Model

Preliminaries

Research Problem & Objective

Literature Review

The MmGA Model

Conclusions and Contributions

Future Works

- Improving the convergence properties towards to the true Pareto front as compared with mGA using
 - An NSGAII inspired elitism method
 - An extended population formation method

Require: Select c_0 non-dominated fronts based on given inbound individuals \mathbf{x}' where maximum $|\mathbf{x}'| = 2N$, $|\mathbf{y}| \rightarrow \text{constant } c_1$

```

1: Procedure MmGAElitism ( $\mathbf{x}', \mathbf{y}, c_0$ )
2:  $\mathbf{z} = \{\neg(\mathbf{x}' \cap \mathbf{y}) \mid \mathbf{z} \in \mathbf{x}'\}$ 
3:  $\mathbf{w} = \text{FNDS}(\mathbf{z})$       /**adopted from (Deb et al., 2002)**/
4:  $i = 1$ 
5: while  $i \leq (2N + c_1)$  do
6:    $\text{CDAssignment}(\mathbf{w}_i)$       /**adopted from (Deb et al., 2002)**/
7:    $i = i + 1$ 
8: end while
9:  $\mathbf{e} = \text{Sort}(\mathbf{w}, \preceq_{CD})$       /** adopted from (Deb et al., 2002)**/
10: return  $\{\mathbf{e} \mid \forall \mathbf{e} \in \neg(\mathbf{x}' \cap \mathbf{y}) \cup \mathbf{y}, |\mathbf{e}| = c_0 + c_1\}$ 
```

An NSGA-II inspired elitism strategy.

The MmGA Model

Preliminaries

Research Problem & Objective

Literature Review

The MmGA Model

Conclusions and Contributions

Future Works

Require: Generate constant n number of populations based on given inbound and constant c_0 members' adoption rate

```

1: Procedure InitializePopulation ( $n, c_0, \mathbf{irm}, \mathbf{rm}, \mathbf{m}$ )
2:  $\mathbf{p}_{init} = \mathbf{irm}$ 
3:  $\mathbf{r} = \{[r_1, \dots, r_n] \mid \forall \mathbf{r} \in \text{random}(\mathbb{N}), \mathbb{N} = [1, 2, \dots], r_k \leq n\}$ 
4:  $\mathbf{d} = [\mathbf{rm}, \mathbf{m}]$ 
5:  $i = 1$ 
6: while  $i \leq \mathbf{d}$  do
7:    $z_{unique} = \{\neg(d_i \cap \mathbf{p}_{init}), \mid \mathbf{p}_{init} \mid \leq n, \forall z_{unique} \in d_i, \mid z_{unique} \mid \leq d_i\}$ 
8:    $z_{sorted} = \{\text{Sort}(z_{unique}, \leq)\}$ 
9:   if  $i = 1$  then /*for rm component*/
10:     $c_1 = c_0 \times (n - \mid \mathbf{irm} \mid)$ 
11:    *Add  $c_1$  members from  $z_{sorted}$  to  $\mathbf{p}_{init}$ 
12:  end if
13:  if  $i = 2$  then /*for m component*/
14:     $c_1 = \{c_0 \times (n - \mid \mathbf{p}_{init} \mid), \mid \mathbf{p}_{init} \mid \neq 0, c_0 > 0\}$ 
15:    for  $j = 1 \rightarrow c_1$  do
16:      *Add ( $r_j$ )th of  $z_{sorted}$  to  $\mathbf{p}_{init}$ 
17:    end for
18:  end if
19:   $i = i + 1$ 
20: end while
21: if  $\mid \mathbf{p}_{init} \mid \leq n$  then /*for new random elements*/
22:   $c_1 = \{n - \mid \mathbf{p}_{init} \mid, \mid \mathbf{p}_{init} \mid \neq 0, c_0 > 0\}$ 
23:  for  $j = 1 \rightarrow c_1$  do
24:    *Add random solution to  $\mathbf{p}_{init}$ 
25:  end for
26: end if
27: return  $\mathbf{p}_{init}$ 

```

An extended population formation procedure,
adapted from Coello and Toscano Pulido (2001);
Coello and Pulido (2005).

The MmGA Model

Preliminaries

Research Problem & Objective

Literature Review

The MmGA Model

Conclusions and Contributions

Future Works

Require: Generate non-dominated solutions for MOP

```

1: Procedure MmGA
2:  $i = 0, \mathbf{p}_{MmGA} = \emptyset$ 
3:  $\mathbf{em} = f(\text{archiveSize}, \text{BiSection}, n) = \emptyset$ 
4: Initialize  $\mathbf{m}_{init}$ 
5:  $\dagger \mathbf{m} = \text{Sort}(\mathbf{m}_{init}, \preceq)$ 
6: while  $i < \text{evaluation}_{Max}$  do
7:    $\dagger \mathbf{p}_{init} = \text{InitializePopulation}(n, \text{ratio}, \mathbf{irm}, \mathbf{rm}, \mathbf{m})$ 
8:    $\dagger \mathbf{p} = \text{Sort}(\mathbf{p}_{init}, \preceq)$ 
9:   repeat
10:     $\mathbf{u} = \text{Apply binary tournament selection on } \mathbf{p}$ 
11:     $\mathbf{v} = \text{Apply two-Point crossover on } \mathbf{u}$ 
12:     $\mathbf{w} = \text{Apply uniform mutation on } \mathbf{v}$ 
13:     $\mathbf{p}_i^{MmGA} = \dagger \text{MmGAElitism}(\mathbf{w}, \mathbf{p}, 1)$ 
14:    until  $\text{nominalConvergence}_{Max}$  is reached
15:     $\mathbf{em}_{MmGA} = \dagger^1 \text{MmGAElitism}(\mathbf{p}_i^{MmGA}, \mathbf{em}, \text{eliteSize})$ 
16:    if  $\mathbf{em}$  is full when trying to insert  $\mathbf{em}_{elite}$  then
17:       $\mathbf{em} = \text{adaptiveGrid}(\mathbf{em}_{elite})$  /*adopted from (Knowles and Corne, 2000)*/
18:    end if
19:     $\mathbf{m} = \dagger^2 \text{MmGAElitism}(\mathbf{p}_i^{MmGA}, \mathbf{m}, \text{eliteSize})$ 
20:    if  $i \bmod \text{replacementCycle}$  then
21:       $\mathbf{rm} = \dagger^3 \text{MmGAElitism}(\mathbf{em}, \mathbf{rm}, \text{eliteSize})$ 
22:    end if
23:     $i = i + 1$ 
24:  end while
25: return  $\mathbf{p}^{MmGA}$ 
26: /* $\dagger^1, \dagger^2, \dagger^3$  are the first, second and third forms of elitism mGA, respectively.*/

```

The pseudo-code of the overall MmGA model.

The MmGA Model

Summary of Experiments with Selected Result

Preliminaries

Research
Problem &
Objective

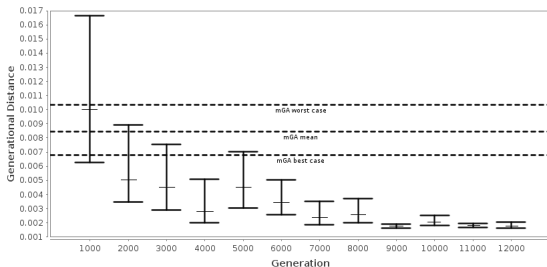
Literature
Review

The MmGA
Model

Conclusions and
Contributions

Future Works

Key result: It achieved fast convergence in I_{gd} with statistical significance results.



A comparison between I_{gd} of mGA (i.e. dotted lines) and bootstrapped I_{gd} of MmGA. The error bars indicate the 95% confidence intervals of the mean I_{gd} results of MmGA.

Conclusions and Contributions

Preliminaries

Research
Problem &
Objective

Literature
Review

The MmGA
Model

**Conclusions and
Contributions**

Future Works

The key contributions of this research are as follows:

- Created an enhanced mGA-based models to provide near optimal solutions with reference to the true Pareto front for undertaking MOPs
- Assessed the proposed models with benchmark MOPs and conducted a comprehensive performance comparison with other similar models

Conclusions and Contributions

Preliminaries

Research Problem & Objective

Literature Review

The MmGA Model

Conclusions and Contributions

Future Works

- Quantified all results with the bootstrap statistical method to confirm the stability of performance (see paper)
- Derived the time complexity analysis using the big-O notation (see paper)
- The details of this research is published: Tan, C. J., Lim, C. P. and Cheah, Y.-N. (2013). A modified micro genetic algorithm for undertaking multi-objective optimization problems, Journal of Intelligent and Fuzzy Systems 24(3): 483-495.

Preliminaries

Research Problem & Objective

Literature Review

The MmGA Model

Conclusions and Contributions

Future Works

The further works of this research are as follows:

- to attempt to measure the performance of the MmGA using other MOP indicators,
- to evaluate the applicability of the MmGA to undertake real-world MOPs, and
- to hybrid EA models and other neural computing models in forming new MOEA models.

Thank You

Visit us at www.wou.edu.my