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Memetic Firefly Algorithm for Combinatorial Optimization

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Motivation

- To show that memetic Firefly algorithm can also be used by solving of combinatorial optimization problems.
- To show that the memetic Firefly is comparable with the well-known heuristics for graph coloring, as Tabucol (Hertz & de Werra, 1987) and HEA (Galinier & Hao, 1999).
- To show that memetic Firefly improves the results of the EA-SAW (Eiben et al. 1998) that is well-known evolutionary algorithm for graph 3-coloring.

Characteristics of the problem

- NP-complete problem
- Constraint Optimization Problem (COP)
- The hardest instances occur near to the *phase transition* (Turner, 1988; Petford & Welsh, 1989; Hayes, 2003)
- Existing algorithms:
  - DSatur (Brelaz, 1979) greedy algorithm,
  - Tabucol (Hertz & de Werra, 1986),
  - EA with method SAW (Eiben et al. 1998),
  - HEA (Galinier & Hao, 1999).

Biological basis of Firefly Algorithm

- Firefly Algorithm (FFA) was proposed by Xin-She Yang in 2007.
- FA is inspired by the flashing behavior of fireflies

Firefly Algorithm

- Population based algorithm

Algorithm 1 Pseudo code of the MFFA algorithm

$t = 0$; $fe = 0$; $found = $ **FALSE**;
$P^{(t)} = \text{InitializeFFA}()$; $best = \emptyset$;
while (!TerminateFFA(fe, $found$)) **do**
    $fe \mathrel{+}= \text{EvaluateFFA}(P^{(t)})$;
    $P' = \text{OrderFFA}(P^{(t)})$;
    $found = \text{FindTheBestFFA}(P^{(t)}, best)$;
    $P^{t+1} = \text{MoveFFA}(P^{t}, P')$;
    t = t+1;
end while

Elements of the MFFA algorithm

- **Representation**: real-valued vector *Yi={wij}*
- **InitializeFFA**: population is initialized randomly
- **EvaluateFFA**: evaluating the solution
- **OrderFFA**: forming an intermediate population
- **FindTheBestFFA**: determining the best solution in the population P(t)
- **MoveFFA**: moving the fireflies according to their neighbour's solutions
- **TerminateFFA**: number of function evaluations

Fitness calculation

- Attractiveness represents weights determining the order in which vertices are to be colored
- Fitness calculation consists of two steps:
  - Weights are transformed into a vertex permutation,
  - The permutation is decoded into graph 3-coloring by DSatur construction heuristic.
- Fitness function counts the number of uncolored vertices

Moving the fireflies

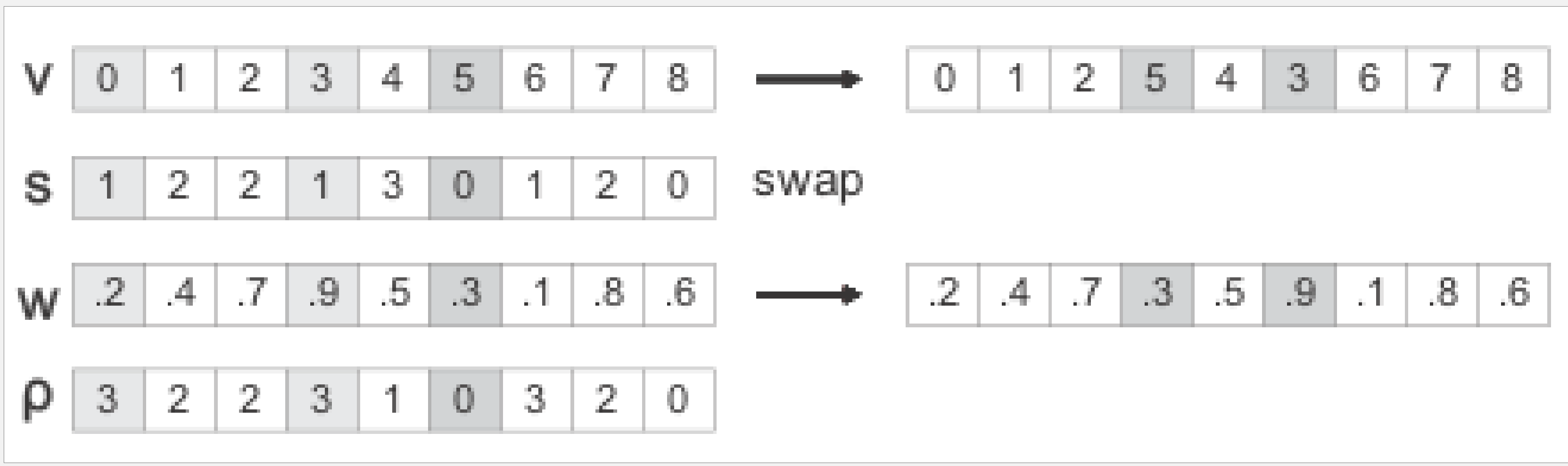
- Calculation of the new position:

$$\mathbf{w}_i = \mathbf{w}_i + \beta_0 \mathbf{e}^{-\gamma r_{i,j}^2}\left(\mathbf{w}_j - \mathbf{w}_i\right) + \alpha\left(rand(0,1) - \frac{1}{2}\right)$$

  - $\mathbf{w}_i$: *i*-th firefly.
  - $\mathbf{w}_j$: *j*-th firefly.
  - β: beta parameter.
  - α: alfa parameter.
  - γ: gama parameter.
  - $rand(0,1)$: The random value in the range [0,1].
- Stochastic large distance exploration

The heuristical swap local search

- Improving the current solution
- Using the heuristical swap unary operator



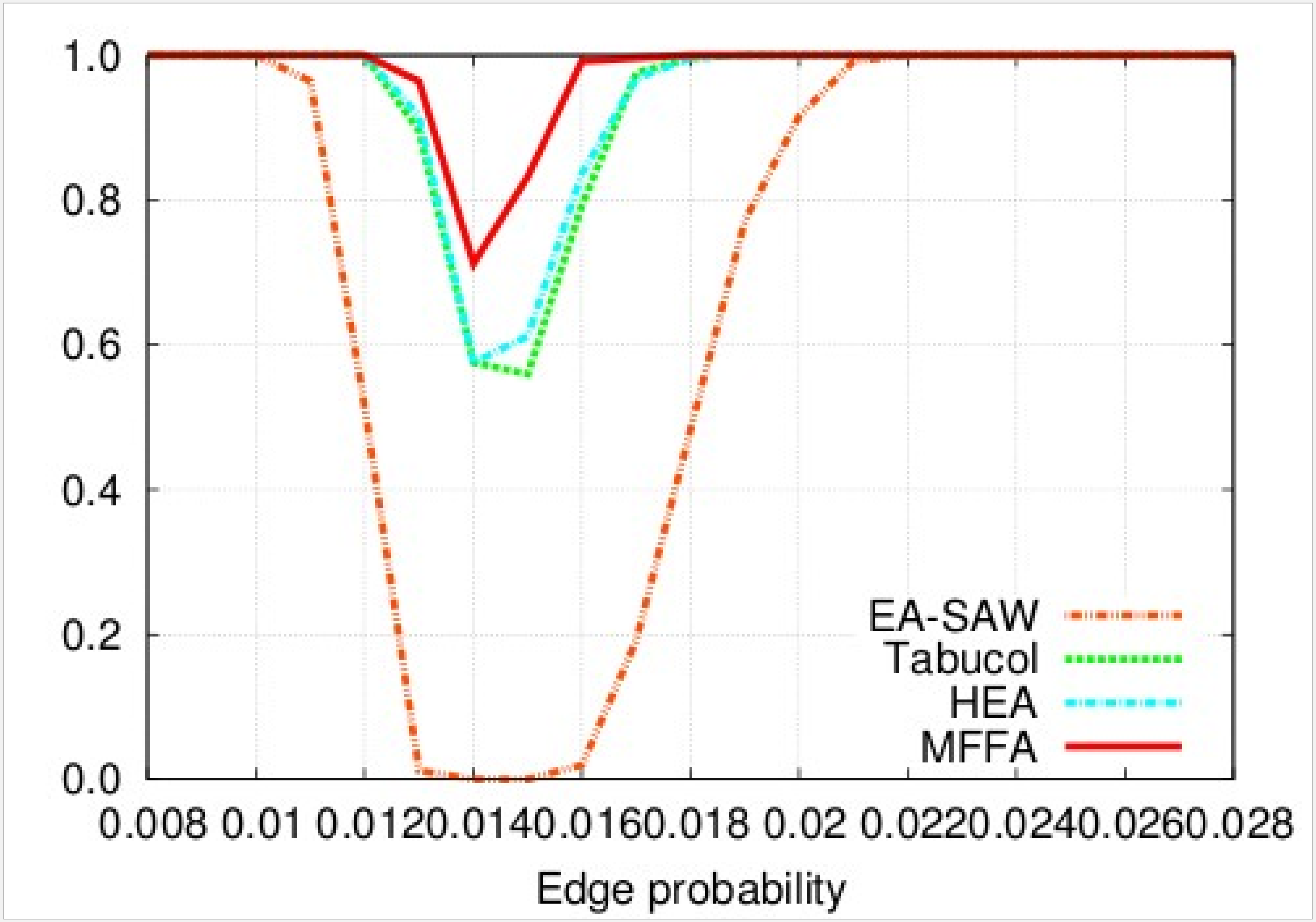
Experiments and results

- Comparison with:
  - Tabucol (Hertz & de Werra, 1986),
  - EA with method SAW (Eiben & al. 1998),
  - HEA (Galinier & Hao, 1999).
- All implementations can be downloaded from Internet
- Characteristics of MFFA:
  - Population size: *NP*=500,
  - Number of objective function evaluations: *FEs*=300,000,
  - Number of runs: 25,
  - $\alpha=0.1$, $\beta=0.1$, $\gamma=0.8$.
- Measures:
  - Success rate (*SR*),
  - Average number of function evaluation (*AES*).

Test problems

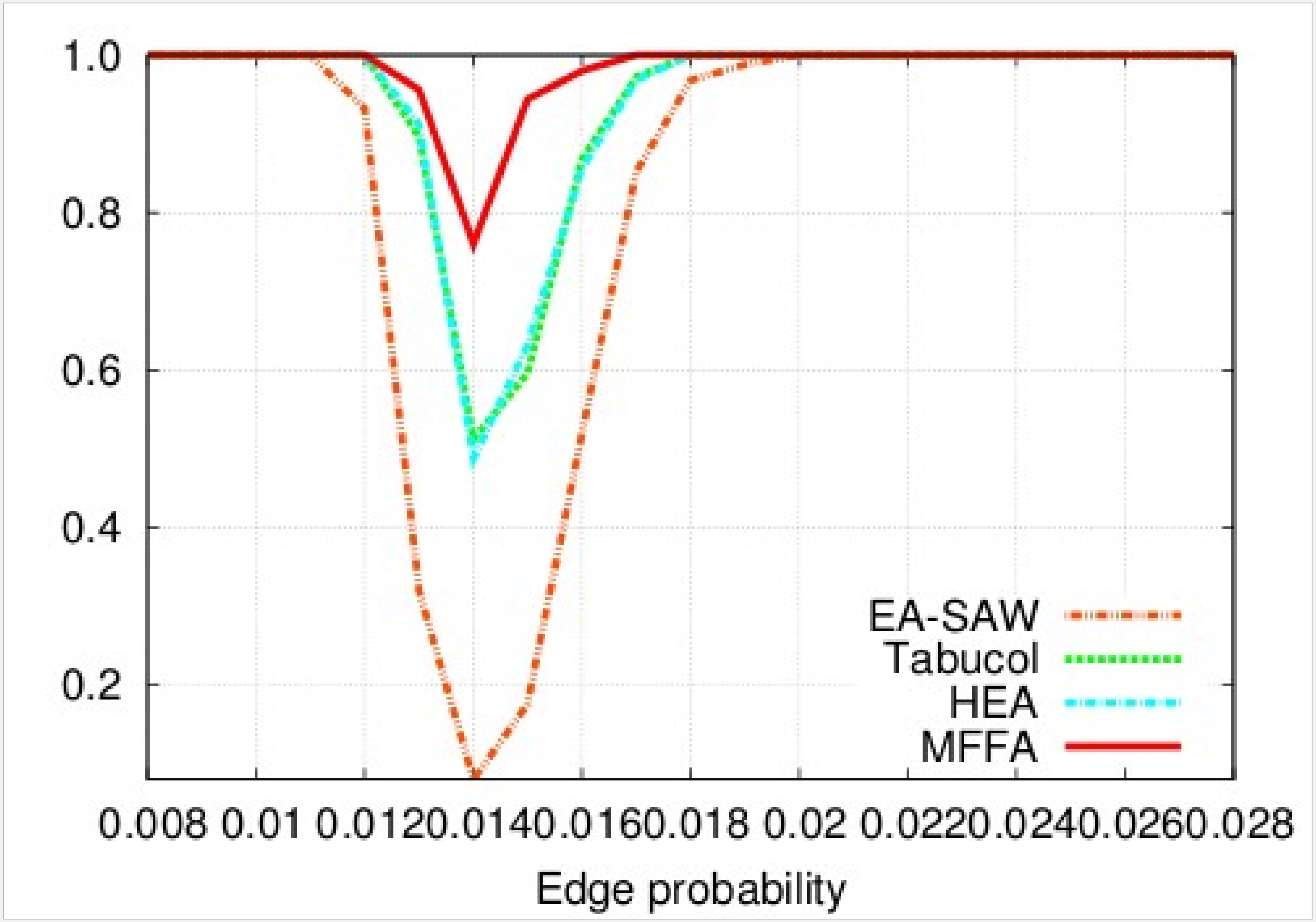
- Random graphs generated by Culbersone graph generator with following characteristics:
  - **types**: equi-partite, uniform, flat;
  - **sizes**: n=500 (also medium-scale graphs);
  - **edge density**: p=0.008…0.028 in steps of 0.001;
  - **seed**: s=1…10.
- Capture the phenomenom of *phase transition*, where graphs are really hard to color
- Phase transition occurs when p=0.014

Influence of the edge density 1/3



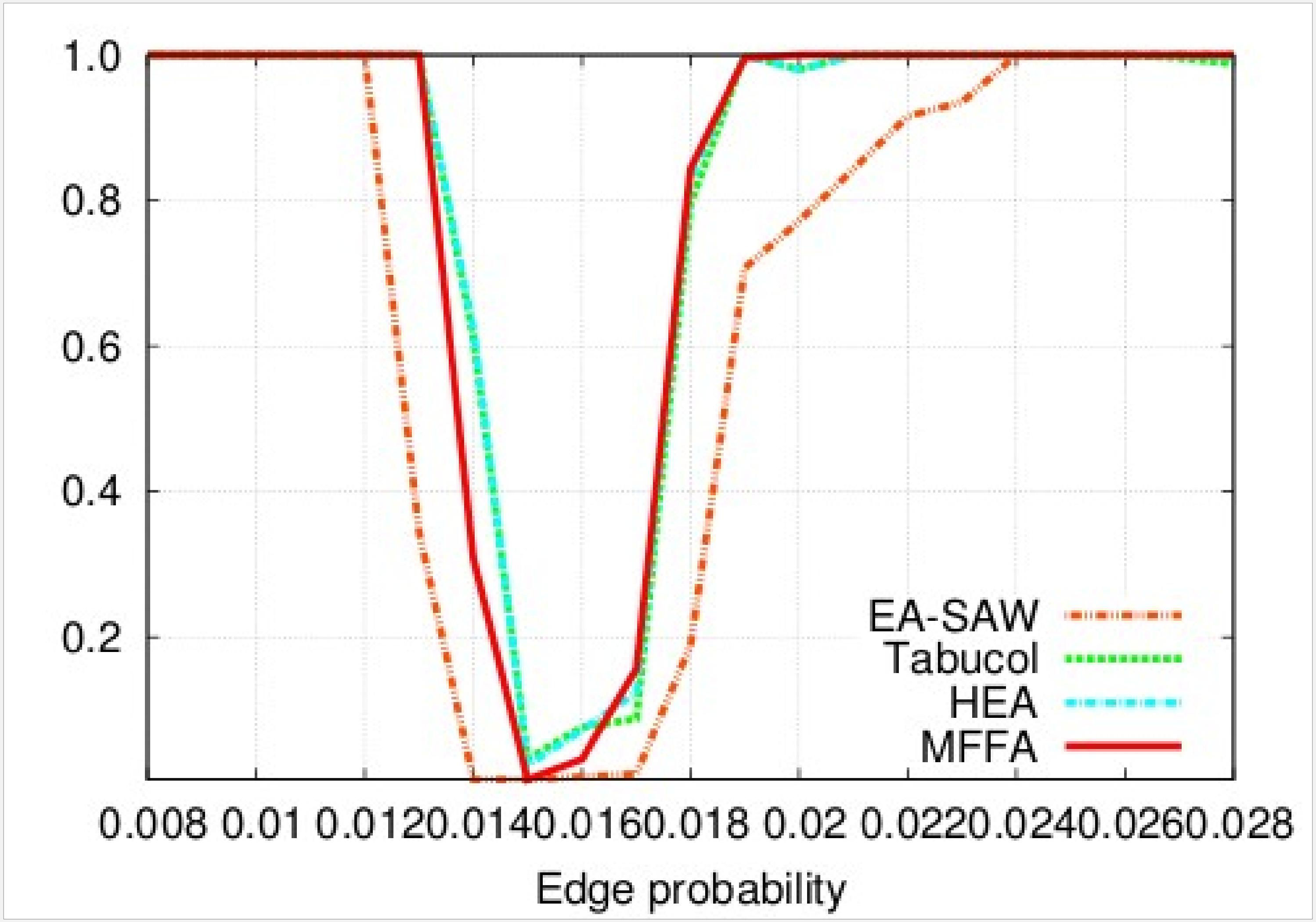
- SR by uniform graphs.

Influence of the edge density 2/3



- SR by equi-partite graphs.

Influence of the edge density 3/3



- SR by flat graphs.

Discussion

- Exploration of search space depends on the best solution, i.e. elitism is used.
- The heuristic swap local search improves the current solutions
- α parameter determines the size of the randomness move within the search space
- Self-adaptation of the α parameter could improve the results of MFFA

Conclusion

- The results of MFFA is comparable with the results of Tabucol and HEA on medium-scale graphs
- MFFA improves results of EA-SAW by solving of all three type of medium-scale graphs
- As a result, MFFA could be successfully applied to solving of graph 3-coloring problem
- In the future, tests on large-scale graphs (1,000 vertices) would be conducted