A Particle Swarm Based Algorithm for Functional Distributed Constraint Optimization Problems

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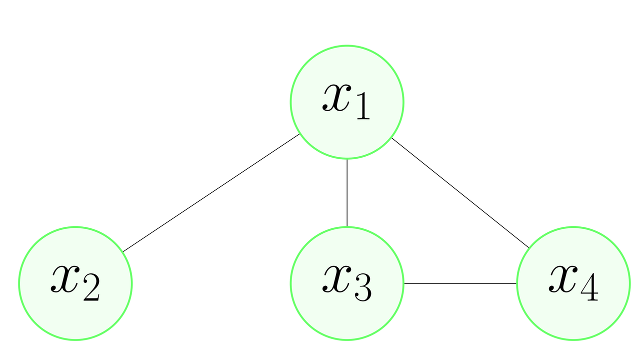
Abstract

Distributed Constraint Optimization Problems (DCOPs) are a widely studied constraint handling framework. The objective of a DCOP algorithm is to optimize a global objective function that can be described as the aggregation of several distributed constraint cost functions. In a DCOP, each of these functions is defined by a set of discrete variables. However, in many applications, such as target tracking or sleep scheduling in sensor networks, continuous valued variables are more suited than the discrete ones. Considering this, Functional DCOPs (F-DCOPs) have been proposed that can explicitly model a problem containing continuous variables. In this paper, we propose a new F-DCOP algorithm, namely Particle Swarm based F-DCOP (PFD), which is inspired by a meta-heuristic, Particle Swarm Optimization (PSO).

The F-DCOP Model



(a) Constraint Graph

$D_i = [-10, 10]$

$f(x_1, x_2) = x_1^2 - x_2^2$

$f(x_1, x_3) = x_1^2 + 2x_1x_3$

$f(x_1, x_4) = 2x_1^2 - 2x_4^2$

$f(x_3, x_4) = x_3^2 + 3x_4^2$

(b) Cost Functions

Figure 1: Example of an F-DCOP.

F-DCOP can be defined as a tuple $\langle A, X, D, F, \alpha \rangle$.

The global objective function,

$$X^* = \underset{X}{\operatorname{argmin}} \sum_{i=1}^{l} f_i(\mathbf{x}_i)$$

The PFD Algorithm

Initialization:
- BFS pseudo tree construction
- Message passing order
- random value assignment

Evaluation:
- calculates constraint cost
- sends the cost to higher priority neighbors

Update:
- Root updates personal and global best.
- Agents update position and velocity component.

For all the particles except the global best particle, the velocity update equation is shown in Equation 1.

$$P_k.v_i(t) = w * P_k.v_i(t-1) + r_1 * c_1 * (P_k.p_{best}(t-1) - P_k.x_i(t-1)) + r_2 * c_2 * (P.g_{best}(t-1) - P_k.x_i(t-1)) \quad (1)$$

When the particle is the global best particle, the velocity update equation is shown in Equation 2.

$$P_k.v_i(t) = -P_k.x_i(t-1) + P.g_{best}(t-1) + w * P_k.v_i(t-1) + \rho * (1 - 2r_2) \quad (2)$$

The position component update equation is the same for all the particles which is defined in Equation 3.

$$P_k.x_i(t) = P_k.x_i(t-1) + P_k.v_i(t) \quad (3)$$

Theoretical Analysis

Proposition 1: *PFD is an anytime algorithm.*

Lemma 1: At *iteration $t + d$, the root is aware of the $P.p_{best}$ and $P.g_{best}$ up to iteration t, where d is the longest path in the pseudo-tree starting from the root.*

Lemma 2: *At iteration $t+d+h$, each agent is aware of the $P.p_{best}$ and $P.g_{best}$ up to iteration t, where h is the height of the pseudo-tree.*

Experimental Results

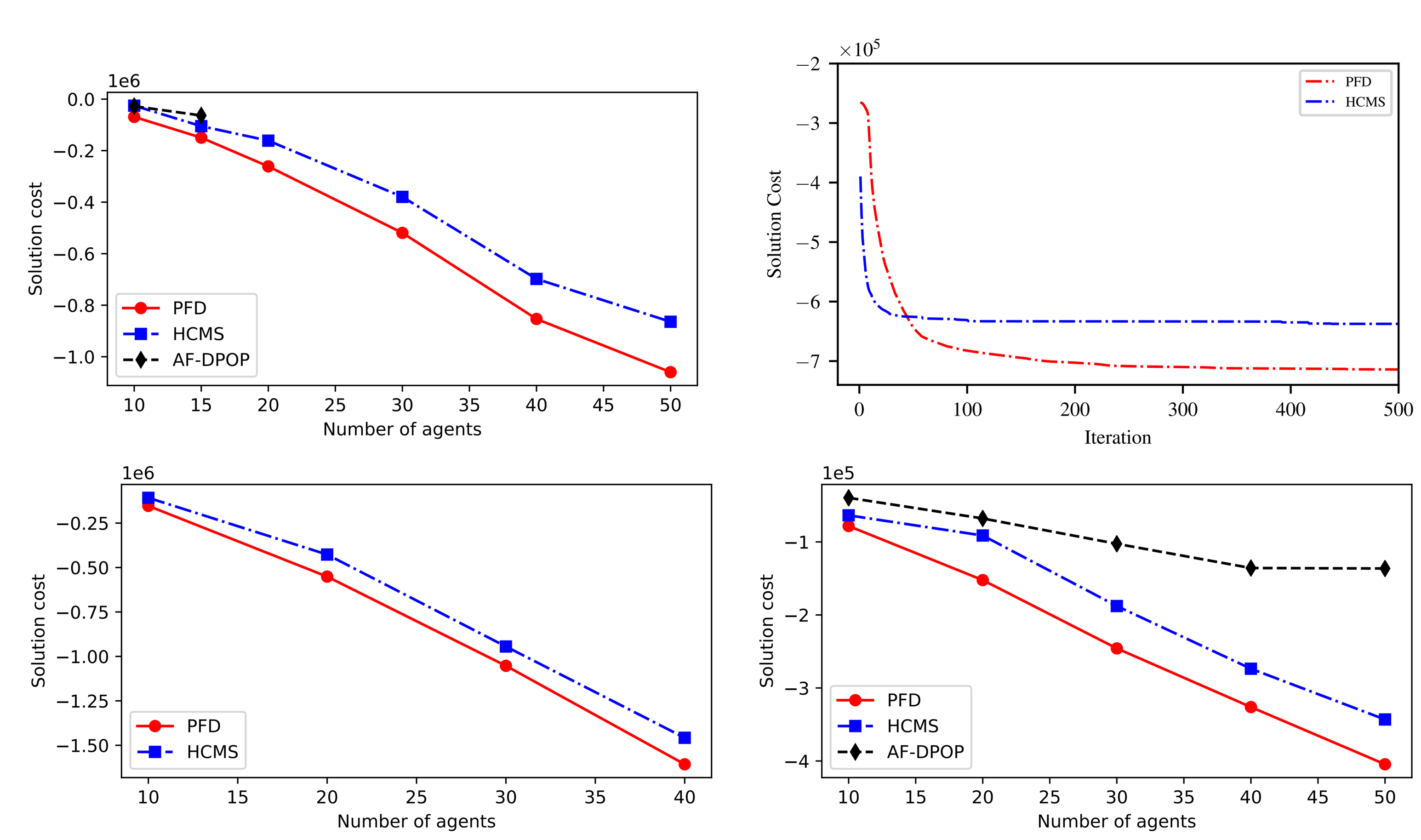


Figure 2: Solution Cost Comparison of PFD and the competing algorithms: Sparse Graph (T.L), Sparse Graph (T.R), Dense Graph (D.L), Random Tree (D.R).

Conclusions and Future Work

- Propose an anytime algorithm called PFD that is inspired by the Particle Swarm Optimization (PSO) technique.
- Theoretically prove that our proposed algorithm PFD is anytime.
- Tailor the guaranteed convergence version of PSO which ensures its convergence to a local optimum.
- Empirical evaluation suggests PFD markedly outperforms the state-of-the-art algorithms, HCMS and AF-DPOP, in terms of solution quality.
- Further investigate the potential of PFD on various F-DCOP applications.
- Explore whether PFD can be extended for multi-objective F-DCOP settings.

References

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