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Interoperability Optimization using a modified PSO algorithm

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ABSTRACT

Optimizing efforts in interoperability implementation is considered a key requirement. This way one can effectively sets up, develops, and evolves intra and inter organizational collaboration. Therefore, the objective of the present paper is to initiate a novel method for linear modeling of the interoperability optimization between involved information systems. Interoperability degree is assessed using a novel Particle Swarm Optimization (PSO) model with dynamic neighborhood topology associated to parallel computation. The idea behind using dynamic neighborhood topology is to overcome premature convergence of PSO algorithm, by well exploring and exploiting the search space for a better solution quality. Parallel computation is used to accelerate calculations especially for complex optimization problems. The obtained results demonstrate good performance of the proposed algorithm in solving interoperability optimization.

Key words: Optimization, metaheuristic, PSO, Interoperability, Parallel computing.

1. INTRODUCTION

This paper presents the application of heuristic mechanisms for optimizing the overall interoperability efficiency in a business collaboration situation. For this end, the interconnection of several information systems located within a single organization, or, across a group of partners in collaboration is involved. Therefore, the present work proposes IMA metric as a measurement method, an interoperability composite metric that involves several aspects.

This proposed heuristic method uses Paralleled Particle Swarm Optimization (PPSO) that includes threads technology (Java) to make multitasking applications taking advantage of parallelism in terms of reduction in computing time and good use of material resources of the machine. The use of appropriate parallel models reduces the computation time and gives better results than the sequential models [1] [2]. Escaping the premature convergence of the method is also a key point on which several researchers conducted their studies and suggested several versions [3-6].

2. INTEROPERABILITY MEASUREMENT (IMA)

In the literature, numerous assessments approaches of interoperability are projected by several researchers. These approaches can be divided into two categories: approaches communicate qualitative making use of maturity measures and approaches use quantitative measures seeable to review interoperability relationships (compatibility measures).

As a matter of truth, a lot of research has tackled the concept of interoperability taking into thought what was advanced higher than. Therefore, completely different metrics and assessment approaches have been developed. Most of those approaches mainly concentrate on maturity problems not solely at the technological field however additionally at the various layers of the company [7]. However, these models simply outline the interoperability enterprise levels [8] [9].

The premise of this work is to measure the interoperability degree taking into consideration the 3 main following aspects:

- Level of interoperability maturity.
- Degree of compatibility between the information systems studied.
- Operational interoperability performance.

2.1 Interoperability classification

At this stage, classification of interoperability measurement turns to be of distinguished importance for several reasons:

1) Generic classifications make sure that all systems are identified;

2) Classifications highlight the systems' characteristics as well as interoperability-related characteristics;

3) Quantitative classifications describe numerically the similarity between systems.

For that purpose, we have a tendency to propose an illustrative classification for interoperability over four axes as delineated in Figure. 1.

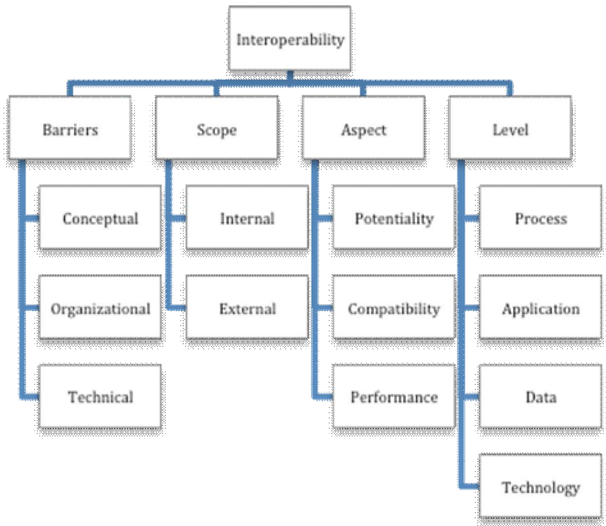

Figure 1: Interoperability classification

2.2 Interoperability measurement

The need and the opportunity to develop interoperability means metrics for evaluating interoperability can be determinate. Associate interoperability measure represents the degree of interoperability that permits knowing the strengths and weaknesses of relationships between systems. At the present stage of analysis, three kinds of interoperability measuring can be considered:

- Interoperability potentiality measure,
- Interoperability compatibility measure,
- Interoperability performance measure.

2.3 IMA approach

In this section, we tend to in brief gift the steps of the IMA approach to define the degree of interoperability. IMA approach consists of the subsequent four steps [10]:
1) Quantifying the interoperation potentiality.
2) Conniving the compatibility degree.
3) Evaluating the Interoperability performance.
4) Aggregating the global degree of interoperability.

A. Quantifying the interoperation potentiality

Numerous models are proposed to depict the potentiality of interoperability. Among these models we quote: OIMM, GIMM, EIMM, LISI, etc [11], [12]. Such models are typically organized in line with five levels.
With the aim of calculate the potential for interoperability «PI», we tend to use a metric which needs the adoption of a maturity model. As a result, the enterprise or information system is assessed in one in all the five levels within IMML (interoperation maturity model level). To calculate the potential degree of interoperability, we tend to adopt the mapping as planned by [13] (see Table 1).

Table 1: Quantification of the maturity of the interoperability

Maturity Level (IMML)	Potentiality quantification
1	0.2
2	0.4
3	0.6
4	0.8
5	1

The potential is calculated using the following formula (See (1)):

$$PI = 0.2 * IMML \quad (1)$$

B. Calculating the compatibility degree

The degree of compatibility is evaluated while employing another version of the matrix proposed by [14] (See Table 2). It consists of a combination of the "levels perspective" and "the barriers perspective", if a criterion in a given area marks satisfaction, the value 1 is assigned; otherwise, the value 0 is given.

Table 2: Interoperability compatibility

	Conceptual		Organizational		Technology	
	syntactic	semantic	authorities responsibilities	Organization	platform	communication
Business	dc11	dc12	dc13	dc14	dc15	dc16
Process	dc21	dc22	dc23	dc24	dc25	dc26
Service	dc31	dc32	dc33	dc34	dc35	dc36
Data	dc41	dc42	dc43	dc44	dc45	dc46

By noting the elementary degree of interoperation compatibility «dcij», (i) takes the values from 1...4, and (j) takes the values from 1...6), and the degree of compatibility «DC» going to be as in formula (2) below:

$$DC = \sum_i \sum_j \frac{dc_{ij}}{24} \quad (2)$$

C. Evaluation of operating performance

The operational performance «PO» assessment is based on the QCD measures. The Interoperability performance is shown in figure 2. The objective of this step is calculating the degree of each kind of operational performance:
- Quality of exchanged information,
- Cost induced by the modification of the interoperable systems,
- Delay (or time) of interoperability.

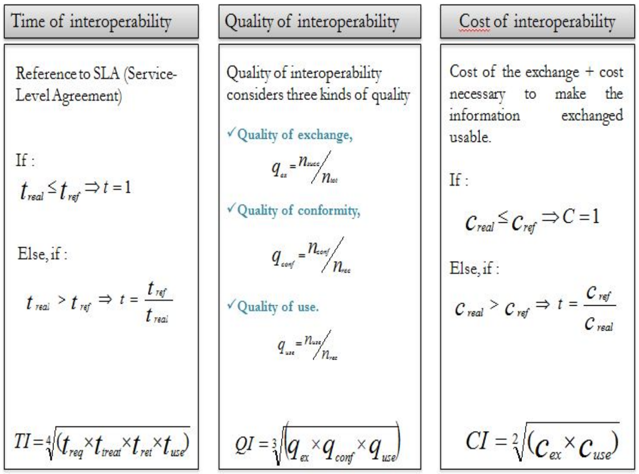

Figure 2: Interoperability performance.

C.1 Time of interoperability

The value of the time of interoperability can be defined by the geometric mean of all the periods of time composing it. This value can be put as follows (See formula (3)):

$$TI = \sqrt[4]{(t_{req} \times t_{treat} \times t_{ret} \times t_{use})} \qquad (3)$$

C.2 Quality of interoperability

The quality of interoperability takes into consideration three kinds of quality:

- The quality of exchange,
- The quality of conformity,
- The quality of use exchange,
- The quality of interoperability can be noted as follows:

$$QI = \sqrt[3]{(q_{ex} \times q_{conf} \times q_{use})} \qquad (4)$$

C.3 Cost of interoperability

The cost of interoperability is defined by the cost of exchange (C_{ex}) and the cost needed to make the information exchanged usable (C_{use}). (See formula (5)):

$$CI = \sqrt{(C_{ex} \times C_{use})} \qquad (5)$$

Last, given the cumulative nature of these three rates, the evaluation of operational performance is calculated through the geometric mean [15] (See formula (6)):

$$PO = \sqrt[3]{(TI \times QI \times CI)} \qquad (6)$$

D. Aggregating the degree of interoperability

Considering the character independent of three previous indicators, the final ratio is done by deciding on the arithmetic mean [8] as an aggregation function (See formula. (7)):

$$IMA = \frac{(PI + DC + PO)}{3} \qquad (7)$$

We can also choose the weighted arithmetic mean. (See formula (8)):

$$IMA = \frac{(n_1 * PI + n_2 * DC + n_3 * PO)}{(n_1 + n_2 + n_3)} \qquad (8)$$

3. COUPLING IMA WITH LINEAR MODELLING

As said, to insert images in *Word,* position the cursor at the insertion point and either use Insert | Picture | From File or copy the image to the Windows clipboard and then Edit | Paste Special | Picture (with "Float over text" unchecked).

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At this stage, the optimum distribution of effort in order to establish a specific organizational collaboration situation is obtained.

IMA is employed, as a result of it's a central assessment approach that aims to quantify interoperability degree of an information system inside its ecosystem on a scalar kind.

It additionally stipulates that interoperability improvement of an information system is obtained through implementing changes within the supporting system. Coupling IMA approach with linear modelling tends to characterize the evolution of the overall interoperability system in a set of interconnected information systems monitors the efforts required to enhance interoperability degree of the collaboration network.

The set of "n" systems (S1, S2,…, Sn) below should be considered:

Si (i =1…n) all systems belongs to the same organization.

Each system contains a single IT infra structure.

The n information systems communicate with each other.

ai = IMA is ratio of the system Si that represents the interoperability level.

I= (ai) is the present vector of interoperability

I'= (a'i) is the result vector of interoperability (See formula. (9))

a'i =∑ Eij aj. (9)

Eij represents the effort to put on the Si system in order to improve the Sj system.

E= (Eij) is the matrix effort for reaching the highest degree of interoperability.

I'= E I.

Or

$$\begin{pmatrix} E_{11} & E_{12} & \dots & E_{1n} \\ E_{21} & E_{22} & \dots & E_{2n} \\ \dots & \dots & \dots & \dots \\ \dots & \dots & \dots & \dots \\ E_{n1} & E_{n2} & \dots & E_{nn} \end{pmatrix} \begin{pmatrix} a_1 \\ a_2 \\ \dots \\ \dots \\ a_n \end{pmatrix} = \begin{pmatrix} a'_1 \\ a'_2 \\ \dots \\ \dots \\ a'_n \end{pmatrix}$$

If all the systems Si are compatible with each other, and if there is no explicit barrier that impedes interaction between the systems, Eij is equivalent to the ratio of workload Nij, which is the workload allocated to the external interfaces to be improved. Si facilitates the Sj IMA. The overall workload was allocated to enhance interoperability.

Eij=Nij/Noverall

In this case, the utmost goal is to reach the optimal interoperability vector.

Therefore, formula (10) was used:

$$a'_i - \sum_i \sum_j E_{ij} \cdot a_i \leq 0 \qquad (10)$$

The constraints are for each j:

$$\sum_i E_{ij} \leq 100\%$$

Eij is to be multiplied with Ni/Noverall with Ni=∑Nij

4. PARALLEL PARTICLE SWARM OPTIMIZATION

PSO is a paradigm inspired from the metaphor of social interaction between individuals in a swarm (like insects, birds, fish). It is an approach based population where particles move around the search space of the problem under a number of influences like the tendency of a particle to follow its best obtained results and the tendency to move towards the best current result among neighboring particles.

A particle i in time t has a position (Xi, t) and a velocity (Vi, t), a memory to remember its best performance and a neighborhood: the set of neighboring particles. The movement of a particle i from its current position (Xi, t) to the following position (Xi, t + 1) depends on three weighted tendencies:

1. Its current speed (Vi, t) (tendency to follow its own path)
2. Its best performance (fitness) (Fi, t) (tendency to retrace its steps)
3. And the best position of its neighbors (Gi, t) (tendency to follow its "friends")

Each particle is presented by its own position vector and velocity vector. The motion of these two vectors in the research space is supervised by the following recursive formulas (11):

$$\begin{cases} V_{id} = V_{id} + C1r1(P_{id} - X_{id}) + C2r2(P_{gd} - X_{id}) \\ X_{id} = X_{id} + V_{id} \end{cases} \qquad (11)$$

X represents the position of the particle in the search space.

V represents the velocity of the particle, i.e. its change of position for each step time.

i represents the index of each particle.

d is the dimension of the optimization problem.

Pi is the best personal position of the particle and Pg is the best position founded in its neighborhood.

C 1 is the cognitive factor and C 2 is the social factor.

r 1 and r 2 are random values that change uniformly in the interval [0, 1] for better exploration of the research space.

4.1 Algorithm

PSO is a cooperative evolutionary technique proposed by James Kennedy and Russel Eberhart and presented as an optimization method for solving optimization problems in 1995 [15]. The pseudo code of the PSO algorithm is presented in Figure. 3.

```
Initialization of the population (positions and velocities)
Do
   For each i = 1 up to number of particles
   If fitness (Xi) < fitness (Pi) then
   Update of Pbest  = Xi
   Updated gbest Pg  = min (Neighbour)
        For each d = 1 to Dimension
          Update speed and position using (11)
        End of
   Finished
Until Stopping criterion is reached
```

Figure 3: Basic PSO pseudo code.

4.2 Neighbourhood

Different neighborhood topologies for particle relationships have been adopted. The most used is the neighborhood known as "circular". The particles are numbered, virtually arranged in a circle and neighborhood definition is done once and for all in terms of numbers. If the neighborhood size is k (including the particle in itself), the corresponding graph is regular of degree k-1.

In general, there are two main types of neighborhood:

The social neighborhood: Defined a priori at the beginning of the process. Simple to program => Less expensive in calculation time

Example: the circular network.

The geographical neighborhood: Existence of a distance in the search space. Recalculate at each iteration => Costly in calculation time.

Example: the network R (i) of the particle i = {j \ d (xi, xj) <r} where r is a positive real.

This is the kind of neighborhood we have chosen for our parallel model.

In this case, the particle movement is changed by adding a new term in the formula (11). It was proposed by [16].

$$\begin{cases} V_{id} = V_{id} + C1r1(P_{id} - X_{id}) + C2r2(P_{gd} - X_{id}) + C3r3(P_{nd} - X_{id}) \\ X_{id} = X_{id} + V_{id} \end{cases}$$

As: Pn is the neighborhood best position; C3: the acceleration factor; r3: random value between 0 and 1.

4.3 The proposed approach

PSO often provides suboptimal solutions when it is applied on difficult problems having many local optimums due to its rapid reduction of diversity where particles become too similar around suboptimal solutions. The proposed approach aims to improve the basic PSO algorithm by using a new concept of evolutionary neighbourhood associated to parallel computing. The use of dynamic neighbourhood allows a better exploration and exploitation of the search space thanks to the updating of the neighbourhoods at each iteration of the algorithm.

The creation of neighbourhoods is done at each new iteration, so the particles change their neighbourhoods throughout the program. This change allows good sharing of information between different groups. For example: a particle i which belongs to a group N5 at the iteration N115 is declared the best of its group (very close to the optimum); then at the iteration N116 this particle i belongs to another group N9 and shares its information with its new group: this sharing improves the movement of its new group and accelerates the movement of the other particles towards the optimum. The use of this kind of neighbourhood is very interesting in terms of the solution quality, as mentioned earlier, it allows a good exploration and exploitation of the search space, but it remains expensive in terms of computation time, especially for complex optimization problems. For that we added the concept of parallelization to our model to overcome this weakness.

The parallelization is based on the use of threads (this technology used in Java for parallel processing). For each iteration, a set of threads are created, each thread is in charge of the PSO processing for its group (neighbourhood). The search for the optimum is done in parallel for all groups.

Each thread executes the PSO processing of an iteration of its groupe of particles, and waits other threads to finish their processing in order to update the neighbourhoods and begin a new iteration. This process repeats itself until a stopping criterion is met. Our neighbourhoods have the shape of spheres, which are updated at each iteration: their centers evolve and the radius changes according to conditions relating to the number of neighbourhoods.

Below the flowchart of the suggested model Figure. 4.

The reader is referred to [17-22] for other models based on PSO method.

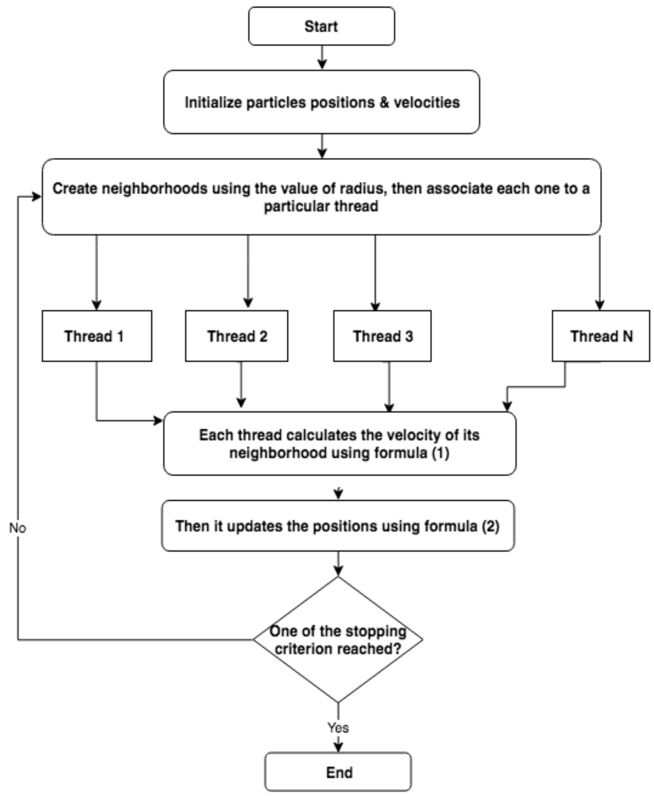

Figure 4: Parallel PSO model flowchart.

5. DESCRIPTION OF THE PRACTICAL CASE

To well illustrate the application of method E-IMA, we take the case of four automated processes that interact within an organization (See Figure 5). These processes are:

- Human Resources (S1);
- Accounting (S2);
- Supply chain (S3);
- Audit and Control Management (S4).

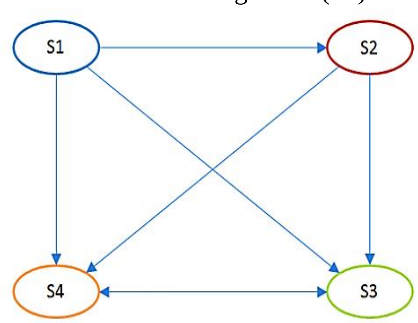

Figure 5: Interaction model between Business processes.

It was found that the interoperability degree of each cited system reached the values of: 0.6, 0.45, 0.52 and 0.37, respectively, after a primary assessment using IMA.

Information System actors, in accordance with business teams, target the following quarter to improve the interoperability degree of the collaboration situation. They also define the objective to reach: 0.7, 0.6, 0.6 and 0.55 values, respectively.

To reach this objective, we use PPSO algorithm to get the optimum matrix of effort that reduces the target function and obeys the constraints in equations (10) and (11). Therefore, we ended up with the following matrix.

88%	**10%**	**17 %**	**0%**
81%	**15%**	**3%**	**6%**
66%	**8%**	**30 %**	**3%**
44.5 %	**13.5 %**	**27 %**	**15 %**

5.1 Results analysis

The result of optimization of the effort matrix allows architects of information systems to have a visibility on the optimal solution possible in the field of solutions. The matrix of the distribution method is optimized successfully, so we improved the interoperability degree, which is IMA metric.

To improve the results, by modifying the target vector a new solution (effort matrix) can be generated automatically. The optimization system is perfectly configurable for any changes. The theatrical results given are a monitor to the integration architects, to estimate efficiency the effort needed to the interoperability of information systems.

To have a good governance of the information systems, it is necessary to have a future solution, which converges towards a theoretical solution. If architects suggest a solution close to our theoretical result, this solution can be accepted. Otherwise the project supervisor invites the architects to give another estimation.

5.2 Interoperability as an optimal control

The result given in this paper offers knowledge on the optimum of possible solutions in the research area. It supports the researchers to find acceptable and practical value from mathematical solution.

We can continually ameliorate the results by adjusting the target interoperability vector; and it is up to the system to generate a different result matrix.

In this paper, the practical case use four processes, when we exceed this number we cannot resolve the system in manual way.

However, the proposed system does not suffer from this restriction problem; and, it offers optimal solutions in certain constraints; moreover, it can be regularly improved.

6. CONCLUSIONS AND FUTURE WORK

This paper proposes an approach to model and optimize the improvement of information system interoperability. In this case, it is a question of planning the distribution of the necessary efforts for the establishment of the collaboration. The reconciliation of the area of interoperability improvement (IMA) with the efficient distribution of efforts in a multi-project framework between information systems, was based on an innovative linear model allowing the monitoring and planning of interoperability. This model is open to be used later by any optimization method in order to improve the objective function to the defined problem. The optimization operations used in this work use PSO particle swarm optimization.

The good results are given by an optimized matrix which allows a good estimate of the effort required for interfacing and interconnecting the information systems involved.

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REFERENCES

1. Y.Zhou and Y.Tan. **GPU-Based Parallel Particle Swarm Optimization.** In: Proceedings of the *IEEE Congress on Evolutionary Computation,* vol. (9), pp. 1493–1500, 2009. https://doi.org/10.1109/CEC.2009.4983119
2. M.Waintraub, R. Schirru and C. Pereira. **Parallel Particle Swarm Optimization Algoritms in Nuclear Problems.** In: International Nuclear Atlantic Conference – INAC, 2009.
3. Ting, T.-O., Rao, M.V.C., Loo, C.K., Ngu, S.-S. **A New Class of Operators to Accelerate Particle Swarm Optimization.** In: Proceedings of *the IEEE Congress on Evolutionary Computation*, vol. (4), pp. 2406– 2410, 2003.
4. Liu, H., Abraham, A., Zhang, W. **A Fuzzy Adaptive Turbulent Particle Swarm Optimization.** International Journal of Innovative Computing and Applications 1(1), 39–47, 2007. https://doi.org/10.1504/IJICA.2007.013400
5. Paquet, U., Engelbrecht, A.P. **A New Particle Swarm Optimizer for LinearlyConstrained Optimization.** In: Proceedings of the *IEEE Congress on Evolutionary Computation*, vol. (1), pp. 227–233, 2003.
6. Parsopoulos, K.E., Plagianakos, V.P., Magoulus, G.D., Vrahatis, M.N. **Objective Function "Strectching" to Alleviate Convergence to Local Minima.** Nonlinear Analysis, Theory, Methods and Applications 47(5), 3419–3424, 2001.

https://doi.org/10.1016/S0362-546X(01)00457-6

7. Kasunic M., Anderson W. **Measuring Systems Interoperability: Challenges and Opportunities.** Technical Note CMU/SEI-2004-TN-003.Carnegie Mellon University, Pittsburgh. (2004).
8. N. Daclin, D. Chen, and B. **Vallespir. Enterprise interoperability measurement-Basic concepts**. in EMOI-INTEROP, 2006.
9. Pardo, Theresa A., and G. Brian Burke. **Improving Government Interoperability: A capability framework for government managers**. Center for technology in government (2008).
10. A. Koulou, N. El Hami, N. Hmina, A. Elmir and B.Bounabat. **A novel approach IMA of interoperability measurement.** In *IEEE 4th International Colloquium in Information Science and Technology (CIST'16).* Tangier. Morocco. Indexed in Scopus, 2016. pp. 665-669, 2016. https://doi.org/10.1109/CIST.2016.7804969
11. T. A. Pardo, T. Nam, and G. B. Burke. **E-Government Interoperability: Interaction of Policy, Management, and Technology Dimensions.** Social Science Computer Review, vol. 30, no. 1, pp. 7–23, Feb. 2012. https://doi.org/10.1177/0894439310392184
12. C. Campos, R. Chalmeta, R. Grangel, and R. Poler. **Maturity Model for Interoperability Potential Measurement.** Information Systems Management, vol. 30, no. 3, pp. 218–234, Jul. 2013. https://doi.org/10.1080/10580530.2013.794630
13. B. Elmir and B. Bounabat. **E-Service Interoperability Measurement within Business Collaboration Networks.** Proceedings of MICS, 2010.
14. D. Chen, B. Vallespir, and N. Daclin. **An Approach for Enterprise Interoperability Measurement**. in MoDISE-EUS, 2008, pp. 1–12.
15. J. Kennedy and R. Eberhart. **Particle Swarm Optimization**. In: Proceedings of the *IEEE International Joint Conference on Neural Networks*, IEEE Press, vol. 8, no. 3, pp. 1943–1948, 1995.
16. B. Bochnek et P. Fory's. **Structural optimization for post buckling behavior using particle swarms.** Struct Multidisc Optim. Pages 521-531, 2006. https://doi.org/10.1007/s00158-006-0044-8
17. Sachin Kumar, Suman Banerjee, Nanda Dulal Jana. **Particle Swarm Optimization Using Blended Crossover Operator.** In: International Journal on Advanced Trends in Computer Science and Engineering (IJATCSE), Vol. 4 No.1, pp. 06 – 09, 2015.
18. P. Rabanal, I. Rodríguez and F. Rubio. **Parallelizing Particle Swarm Optimization.** In a Functional Programming Environment. In Algorithms2014: vol. 7, pp. 554–581, 2014. https://doi.org/10.3390/a7040554
19. K. Byung-I and G. Alan. **Parallel asynchronous particle swarm optimization.** International Journal For Numerical Methods In Engineering, vol. 67, pp. 578-595, 2006 https://doi.org/10.1002/nme.1646
20. M. Zemzami, A. Elhami, A. Makhloufi, N. Elhami, M. Itmi, and N. Hmina: **Electrical Power Transmission Optimization based on a New Version of PSO Algorithm**. (Published 22/02/17 DOI: 10.21494/ISTE.OP.2017.0127). 2017. https://doi.org/10.21494/ISTE.OP.2017.0127
21. M. Zemzami, N.Elhami, M.Itmi and N.Hmina. **A New Parallel Approach For The Exploitation Of The Search Space Based On PSO Algorithm**. In *IEEE 4th International Colloquium in Information Science and Technology (CIST'16).* Tangier. Morocco. Scopus Indexed, 2016. https://doi.org/10.1109/CIST.2016.7805024

M. Zemzami, A. Elhami, A. Makhloufi, N. Elhami, M. Itmi, and N. Hmina. **Applying a new parallelized version of PSO algorithm for electrical power transmission.** International Conference on Materials Engineering and Nanotechnology (ICMEN'17). Kuala Lumpur, Malizia. Indexed by Ei Compendex and Scopus, 2017. https://doi.org/10.1088/1757-899X/205/1/012032