Parallelization of Memetic Algorithms and Electromagnetism Metaheuristics for the Problem of Scheduling in the production Systems of HFS type

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Abstract
The metaheuristics are approximation methods which deal with difficult optimization problems. The Work that we present in this paper has primarily as an objective the adaptation and the implementation of two advanced metaheuristics which are the Memetic Algorithms (MA) and the Electromagnetism Metaheuristic (EM) applied in the production systems of Hybrid Flow Shop (HFS) type for the problem of scheduling. The Memetic Algorithms or hybrid genetic algorithms are advanced metaheuristic ones introduced by Moscato in 1989. Electromagnetism Metaheuristic (EM) draws its inspiration in the electromagnetic law of Coulomb on the particles charged. We will propose an adaptation of two methods to the discrete case on the problems of scheduling with the production systems (HFS). We present then a comparison between the Memetic Algorithms (MA), the Parallel Memetic Algorithms with Migration (PMA_MIG) and then we present a comparison between Electromagnetism Metaheuristic (EM) and Parallel Electromagnetism Metaheuristic with migration (PEM_MIG). Finally we give the results obtained by its algorithms applied to HFSs (HFS4: FH3 (P4, P2, P3) | | Cmax and HFS4: FH2 (P3, P2) | | Cmax) for the two problems: scheduling and assignment.
Keywords: *advanced Metaheuristics, Hybrid Flow Shop (HFS), Memetic Algorithms (MA), Electromagnetism Metaheuristic (EM), and Parallelism.*

1. Introduction

The objective of this work was to simulate two advanced metaheuristic called “MA and EM” and to study the contribution of parallelism in the improvement of the performances of these algorithms. The dealt problem is the scheduling of the production systems work of the type FSH. The complexity of this system lies in the nature of the problems itself.
It has a double complexity, on one hand it is necessary to find a sequence of work and on the other hand it is necessary to find an assignment as of this work to the resources in order to optimize a performance criterion such as Cmax (**Cmax: the total completion time of treatment or works**).
The general goal was the minimization of the time of completion of work (Optimization of a criterion of performance: Cmax).
Then we'll initially simulate MA and EM in manner Sequential and see if the time of simulation becomes more or less considerable. Finally, we'll be oriented to the Parallelization of two advanced metaheuristics.

2. Scheduling problem of production systems of HFS

2.1 Presentation of Hybrid Flow Shop

The model of Hybrid Flow Shop (HFS) is an extension of the model of Flow Shop.

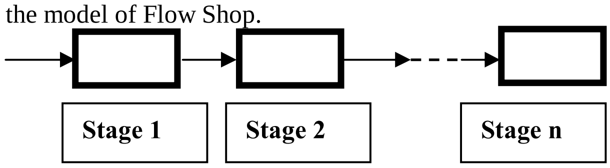

Fig. 1 Organization in Flow Shop [1, 2].

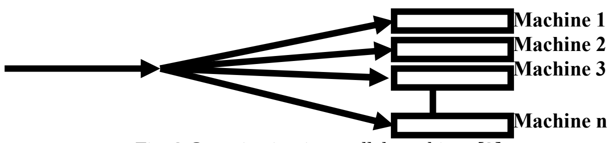

Fig. 2 Organization in parallel machines [2].

2.2 Organization in Hybrid Flow Shop (HFS)

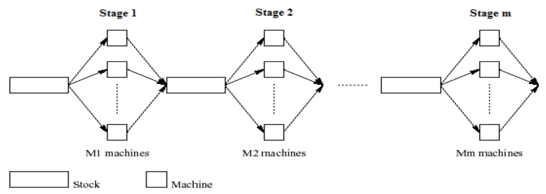

Fig. 3 Hydrid Flow Shop (HFS) [5].

2.3 Scheduling in the HFS

Scheduling in the HFS consists with:
• To find a sequence adequate of the jobs in entry.
• To find an assignment of the jobs on the various machines of the various stages.

3 Of which objective:

• Optimization of a criterion of performance.
Among the criteria one can quote Cmax, Fmax,… etc

4. Methods of resolution

It consists in finding a better solution who minimizes (or maximizes), according to the type of the problem, the selected criterion of performance. Among the methods, with the exact resolution and the approximate resolution (metaheuristics).

4.1 Approximate resolution

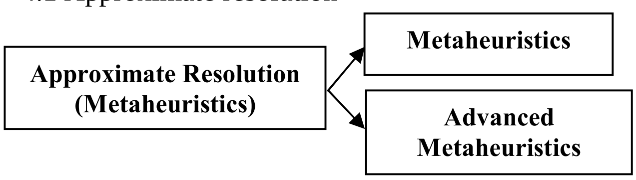

Fig. 4 Approximate Resolution.

5. Metaheuristics

It is a new generation of approximate methods. It allows the resolution of the problems of optimization of big size. Each metaheuristics is based on its own concepts and principles.

5.1 Objectives of the metaheuristics

The metaheuristics ones make it possible to guide research with an optimal solution and the effective exploration of the space of research. Those are mechanisms making it possible to avoid blocking.

5.2 Metaheuristics and Advanced Metaheuristics most known

We can quote among Metaheuristics and advanced Metaheuristics most known: research taboo [3], method of the kangaroo, the descent [4], Simulated Annealing [5], Genetic Algorithms [8], Particle Swarm Optimization method (PSO)) [6,7], the Memetic Algorithms (MA) [8], Scatter Search [8], Electromagnetism Metaheuristic (EM) [9,10].

6. Advanced Metaheuristics

The metaheuristics are very powerful for the resolution of a great number of problems and give better results, but one can note some defects like the limit to find a minimum total in a finished time, difficulties of adapting algorithms to certain problems, for certain problems they are not more powerful than the exact methods, some do not give success in connection with the intensification and diversification. To go further in the research solution, it is necessary for all to be able to detect new solutions. The algorithms containing populations present a private interest: parallelism necessary in the search for the solutions [11,12].

6.1 Memetic Algorithms

The Memetic Algorithms or hybrid Genetic Algorithms are the metaheuristic advanced introduced by MOSCATO in 1989 [5], the principal idea of this technique is to make an genetic algorithm more effective by the addition of a local research in addition to the change.
One of the general observations coming from the implementation of a basic genetic algorithm is often the low speed of convergence of the algorithm.
The idea of Moscato is thus to add a local research which can be a method of descent or a more advanced local research (reheated simulated or seeks taboo for example).
This local research will be applied to all new individual obtained during research.
It is obvious that this simple modification involves deep changes in the behavior of the algorithm.

A simple Memetic Algorithm (MA) is given below:

1: Initialization: to generate an initial population **P** of solutions with size = **N**
2: To apply a Local Research **LR** to each solution of **P**
3: **Repeat**
4: To select two solution **X** and **X'** with a technique of selection
5: To cross two parents **X** and **X'** to train children there
6: **For** each child there
7: To **improve** this solution with **LR**
8: To **apply** a change to there
9: To **choose** a solution to be replaced there **y'** and to replace it by their **y** in the population
10: **End For**
11: **Until criterion of stop**.

The intensification in this algorithm is produced by the application of the local research and the operator of change ensures the diversification of the method [4, 5].

6.2 Electromagnetism Metaheuristic (EM)

6.2.1 Definition

The EM is a method with recent particles.
At introduced by Birbill (2003) [9, 10].
Used to optimize nonlinear continuous functions.

6.2.2 Principle

Its inspiration in the Coulomb law draws EM on the charged particles [9, 10].

6.2.3 The Coulomb law

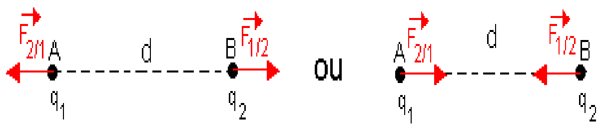

Fig. 5 Principle of the Coulomb law.

6.2.3.1 The formula of F:

$$\|F\| = K|q_1|.|q_2| / d^2$$

- q_i : charge of each particle i.
- $F_{i/j}$: particle i exerts a force (attraction/ repulsion) on particle j.
- d : the distance between two particles.
- k : constant.

6.2.3.2 Parameters of the Coulomb law

•There is a repulsion if $q_1.q_2 > 0$.

•There is an attraction if $q_1.q_2 < 0$.

•The common value $\|F\|$ of these forces is proportional to the loads q_1 and q_2 and inversely proportional to the square of the distance between A and B.
•the particles (or solutions) having ''bad properties'' (or negatively charged according to the law with Coulomb) exert a force of repulsion on the other particles.
•the particles having "good properties" (or positively charged according to the law with Coulomb) exert an attraction force on the other particles.

6.2.3.3 Example

The following figure illustrates the displacement of a particle located at the position x_4 which undergoes the forces of repulsion of the particles located at the positions x_1 and x_3 and the attraction force of the particle located at the position x_2.

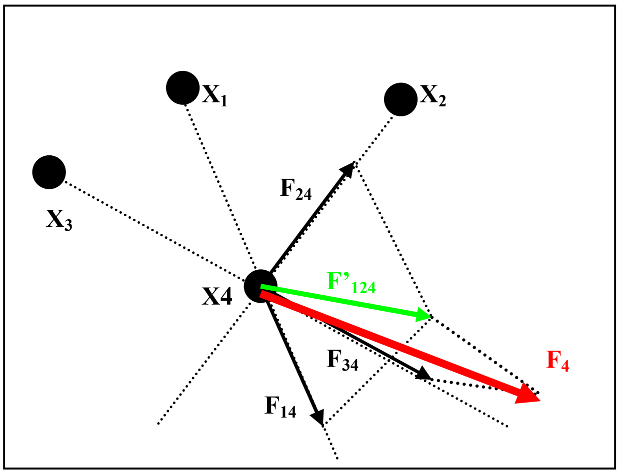

Fig. 6 Force exerted on particle 4 by particles 1, 2 and 3 [10].

Particles 1 and 3 exert a force of repulsion (F_{14}) and (F_{34}) on particle 4 and particle 2 exerts an attraction force (F_{24}) on particle 4.
The force F'_{124} it is the sum of the forces F_{14} and F_{34}. The force F_4 it is the sum of the forces F'_{124} and F_{24} i.e. the total force.

6.2.3.4 A particle i at the step k has the following characteristics

- Its current position $X_{i,k}$.

• The best position of its $X_{best,k}$.
• Its charge $q_{i,k}$.
• Its force F_i^k.
• $F(x_j,k)$ value of the function to optimize f at the x_j point, k where j is a particle.

6.2.3.5 General algorithm of EM (Algorithm. 1: General algorithm of EM [10])

1: **BEGIN**
2: $k = 0$;
3: **For** (each particle i) **Then**
4: $X_{i,0}$ = GenerePosition () ;
5: **End For**
6: **While** ($k \le MaxIter$) **Then**
7: **For** (each particle i) **Then**
8: $Q_{i,k}$ = Calcul New Charge () ;
9: $F_{i,k}$ = Calcul New Force () ;
10: $X_{i,k+1}$ = Calcul New Position () ;
11: $X_{i,k}$ = Update () ;
12: **End For**
13: $k := k+1$;
14: **End While**
15: **END**.

7. Parallelization of the Memetic Algorithms (PMA)

7.1 Weaknesses of the sequential memetic algorithms

The Sequential Memetic Algorithms (SMA) show their interest in the field of the scheduling of the workshops of the type Hybrid Flow Shop (HFS) but they present several weak points quote for examples the storage memory, the evaluation of the fitness, the centralized diagram of selection, the time of simulation…
1. Storage memory.
2. The evaluation of the fitness.
3. The centralized diagram of selection.
4. The time of simulation.

7.2 The standard model of Master /Slaves

There exist several models to implement the distributed model, the model completely distributed and the Master /Slaves model that is simplest. It consists in using the standard memetic algorithm applied to only one population but by carrying out stages of evaluation in parallel. The stage of selection cannot be carried out in parallel because it requires a total knowledge of the costs of all the individuals [6].
The principal processor (master) controls the population and distributes individuals to the processors slaves. These processors will carry out the operations of crossing, change and evaluate the children. After the evaluation the Master gathers the results and applies the replacement to produce the new generation to be managed.

7.3 Description of algorithm PMA of migration

The algorithm is implemented in mode Master /Slaves. Initially the Master generates an initial population and divides it into “P” under populations (“P” being the number of slaves). Each slave carries out a Sequential Memetic Algorithm (SMA) for a number “N” of iterations, with “N” the interval which separates two operations from migration.
The number of migrations to be carried out is determined by the frequency of the latter if it is frequent or not very frequent. Indeed, the number of migration to be carried out and cuts it “N” of the interval of migration are directly calculated starting from the frequency of migration and the full number of iterations to be carried out. At the point of migration, the Master recovers the results of the research carried out by the various slaves and lunch the operation of migration.

8. Parallelization of Electromagnetism Metaheuristic (PEM)

8.1 Description of algorithm PEM of migration

The algorithm is implemented in mode Master /Slaves. Initially the Master generates an initial whole of particles and divides it into “P” subset of particles (“P” being the number of slaves). Each slave carries out an algorithm of sequential (EM) for a number “N” of iterations. At the point of migration, the Master recovers the results of the research carried out by the various slaves and lances the operation of migration.

9. Numerical simulation and results

For better studying the problem of scheduling of the HFS4 (a stock in entry and inter stages) one will consider two problems of HFS4 (FH3 (P4, P2, P3) | | Cmax and FH2 (P3, P2) | | Cmax) and for each varied the number of parts to be scheduled what enables us to obtain four (4) problems for each one. First is FH3 (P4, P2, P3) | | Cmax (Fig. 7) and the second FH2 (P3, P2) | | Cmax (Fig. 8).

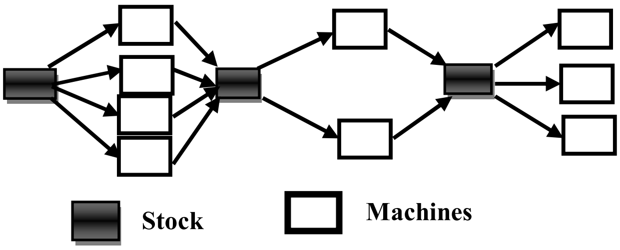

Fig. 7 Structure of a HFS4: FH3 (P4, P2, P3) | | Cmax.

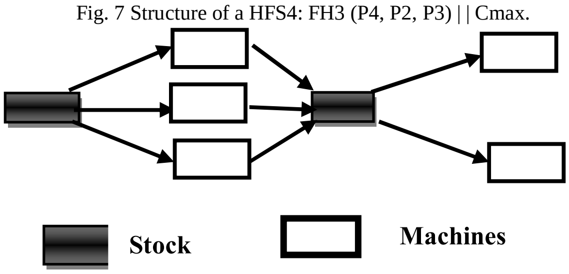

Fig. 8 Structure of a HFS4: FH2 (P3, P2) | | Cmax.

9.1 Application of the PMA_MIG and the PEM_MIG

The Parallel Memetic Algorithms with migration (PMA_MIG) and Parallel Electromagnetism Metaheuristic with migration (PEM_MIG) were implemented on a computer having architecture with shared memory, but this implementation depends on a number of parameters. The success of this strategy of Parallelization is bound by the influences of these parameters.
To study these parameters three values of the frequency were taken: 40%, 60% and 80%. This frequency determines the number of migrations to carry out during the execution of algorithms PMA_MIG and PEM_MIG as well as the interval which separates two operations from migration.

9.2 Application of the PMA_MIG on the HFS4: FH3 (P4, P2, P3) | | Cmax and on the HFS4: FH2 (P3, P2) | | Cmax

For simulation we fix the method of Local Research (LR) used by the descent, we take as number of threads 4 and we change for each number of parts the frequency of migration of 40%, 60% and 80%. One took the average of the ten tests for the four (4) problems by varying the number of parts (N) to be scheduled (5, 10, 20 and 50 parts), the results of Cmax are given by the graphs illustrated by the following Fig. 9 and Fig. 10:

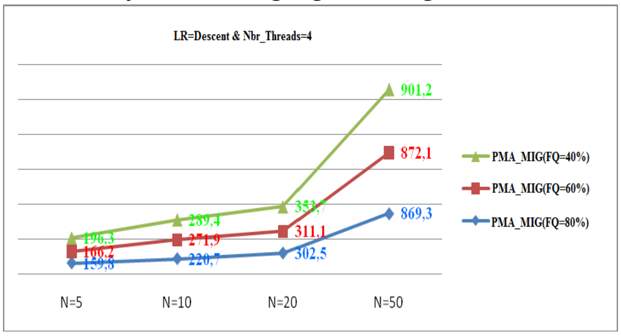

Fig. 9 Graph of variation of Cmax_Moy for the HFS4: FH3 (P4, P2, P3) | | Cmax with the application of the PMA_MIG by varying the frequency of migration.

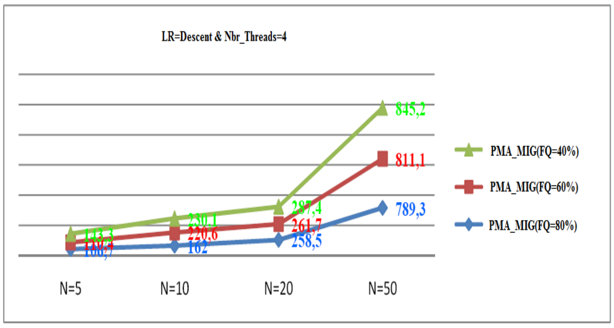

Fig. 10 Graph of variation of Cmax_Moy for the HFS4: FH2 (P3, P2) | | Cmax with the application of the PMA_MIG by varying the frequency of migration.

9.3 Application of PEM_MIG on the HFS4: FH3 (P4, P2, P3) | | Cmax and on the HFS4: FH2 (P3, P2) | | Cmax

For the simulation one taken as number of threads= 3 and one changed for each number of parts (N) the frequency of migration of 40%, 60% and 80% and took the average of the ten tests for the four (4) problems N = 5, 10, 20 and 50, the results of Cmax are given by the two graphs illustrated by the following Fig. 11 and Fig. 12:

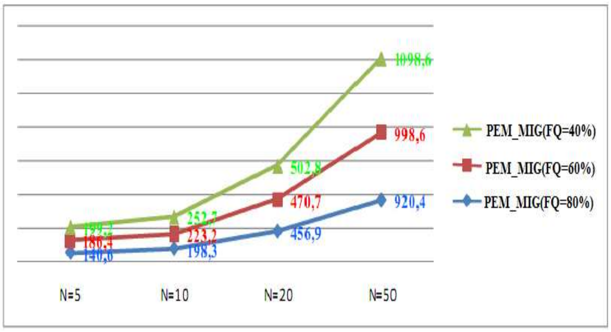

Fig. 11 Graph of variation of Cmax_Moy for the HFS4: FH3 (P4, P2, P3) | | Cmax with the application of the PEM_MIG by varying the frequency of migration.

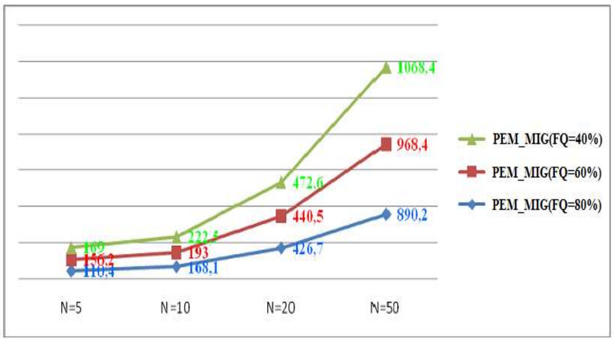

Fig. 12 Graph of variation of Cmax_Moy for the HFS4: FH2 (P3, P2) | | Cmax with the application of the PEM_MIG by varying the frequency of migration.

10. Comparison enters the PMA_MIG, MA, the PEM_MIG and EM on the HFS4: FH3 and HFS4: FH2 | | Cmax

For the two algorithms: MA and PMA_MIG one will fix the local research by the descent. For the PMA_MIG and the PEM_MIG the number of threads is fixed at 3 and the frequency with 80%.

The four (4) algorithms are applied to the HFS4: FH3 (P4, P2, P3) | | Cmax and for the four (4) problems of which the number of parts (N) varies as follows: N = 5, N = 10, N = 20 and N = 50.

The results of the comparison are given by the two graphs illustrated by the Fig. 13 and the Fig. 14.

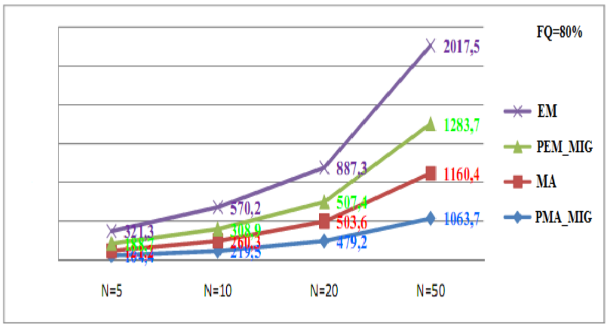

Fig. 13 Graph of variation of Cmax_Moy by the comparison enters the PMA_MIG, MA, the PEM_MIG and EM with the increase in the number of parts (N) on the HFS4: FH3 (P4, P2, P3) | | Cmax.

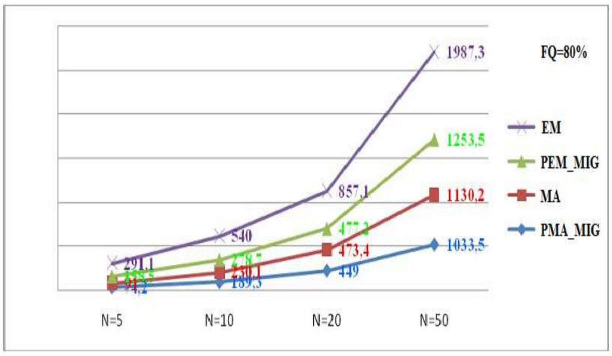

Fig. 14 Graph of variation of Cmax_Moy by the comparison enters the PMA_MIG, MA, the PEM_MIG and EM with the increase in the number of parts (N) on the HFS4: FH2 (P3, P2) | | Cmax.

According to the graphs below, we notice that the PMA_MIG presents a considerable improvement compared to MA sequential, the PEM_MIG and EM sequential with regard to the quality of the solutions obtained, and more the system is complex in addition, the algorithm manages to improve this quality.

11. Conclusion and Future Works

In this paper we gave practical details on two algorithms PMA_MIG and PEM_MIG and we implemented these algorithms on Hybrid Flow Shop (HFS) which were tested on plays of test generated in a random way. We analyzed the results obtained by the plays of test and the implementation of the algorithms. We approached a comparison between the Sequential Memetic Algorithms (SMA), the Parallels Memetics Algorithms with Migration (PMA_MIG), Electromagnetism Metaheuristic (EM) and Parallel Electromagnetism Metaheuristic with Migration (PEM_MIG).

Future Works:

To apply the Memetic Algorithms (MA) and the Electromagnetism Metaheuristic (EM) to other problems with other types of production systems such as Flow-Shop, Job Shop and Open Shop, and to apply other methods of Parallelization of MA and EM and that to grids computing and clusters.

12. References

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