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Message of MOMA Journal Editor-In-Chief

This journal concerns both the national and international scientific community and will be primarily focusing on Models and Optimisation of Systems. Systems will be utilized in different applications for example, Web technologies, Information Systems, Decision Systems, Embedded Systems, Control-command Systems and Real-time Systems. Space of journal is also dedicated to mathematical analysis like functional spaces, polynomial computing etc.

This edition is dedicated to the workshop IWMCS'2014organized by the Ibn Khaldoun of Tiaret during 01-02 December 2014. IWMCS' 2014 workshop on mathematics and computer science, discussed formal approaches and optimization of numerical models.

We have selected eleven papers among nineteen accepted submission of IWMCS'2014.

We would like to express our gratitude to everyone who has contributed towards the success of this edition.

Special thanks to the institution of Ibn khaldoun University of Tiaret to accept to support publication charges of the present issue.

Sincerely yours,
Dr.Mostefa BELARBI

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heterogeneous Multiprocessor Architecture

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Abstract—Analyse data issued from Social networks, large scale wireless networks, .. is computation intensive, and submitted to soft or hard real time constraints. The main characteristic of these kind of applications is that the execution time is greater than the deadline. Thus, mono processor architectures can not satisfy real time requirement of this type of applications. Multiprocessors nowadays architectures consists of numerous processors on one chip and allows to run tasks in parallel manner and can handle the overrun of these applications. In this paper, we present a novel online scheduler for real times tasks where execution time is greater than deadline. As application example, we use MapReduce Real time environments to extract simulation parameters and run tests on simS simulateur.

I.INTRODUCTION

Real time schedulers schedule tasks based on their real time charactiristics. Sporadic real time charactiristics are the Arrival time (R), deadline (D), least period of interactivation (P) , and worst case execution time WCET or C. In general, The relative deadline is greater than the execution time. However, Intensive applications deals with a huge amount of data and the WCET
is at least equal to deadline.
An important part of processing of an intesive computing application can be run in parrallel. That makes this applications more suitable to be run on multiprocessor architectures than on monoprocessors one. More than that, not any task set can be schedulable on one core architecture.
Most real time scheduling works focus on homogeneous MP- SoCs where all processors have the same speed and the same power consumption. However, Heterogeneous MPSoCs are more adiquate in terms of energy consumption and computing speed.
In this work, we focus on scheduling intensive real time tasks with energy constraints on uniform hardware architectures. The aim of the work is to decompose the real time task, to parrallel independant jobs with thier own real time charactiristics and we present our novel on line job-scheduler.
Unfortunately, schedulability test for heterogeneous are much harder, it depends not only on tasks, but on wich processor will run wich task.

II. BACKGROUND

In this work, we consider a set of n sporadic tasks on m processors. Each task is characterized by quadruple (R: Arrival Time, Period Between two activations: P, Deadline: D, WCET: Worst Case Execution Time). Each task is independant, and have an implicit parrallelized sections.
First, we will present prior works and implementation of Map
Reduce Real time environments.

A. Taxonomy of multiprocessors

In terms of heterogeniety, MPSoCs can be classified as :

- Homogenoues

Each task or job is run at the same speed on each processor and consumes the same energy.

- Unifrom

Processors may habe different speeds, but a task that runs in 3 time units on a processor with speed 1, run in 1.5 time units on a processor with speed 2, and 0.75 on processor of speed 4. Each processors consumes at least quadratic of speed on energy compared to a processor with speed 1.

- Unrelated heterogenous

The execution time and the consumed energy depends on the task and the processor at the same time.
In this work we will focus on uniform architectures only.

B. Map Reduce Real Time environments

First, we will provide an overview on Map Reduce and its open source implementation Hadoop, and we focus after on Real-time Map Reduce environments, Exactly Hadoop real time implementations and Misco RT. We will discuss them strength points and weaknesses. A. MapReduce
MapReduce [1] is parallelized, distributed platform for large scale data processing. It virtualizes task and data mapping and scheduling, communication, running failure, fault tolerance and all execution details.
Map Reduce is quite simple, it split a big computing task [10] to smaller ones, each sub-task is affected a worker node. These splits are independent and each worker lunches a different piece of input data. Task independence allows running tasks in parallel manor and the re-run possibility for fault tolerance. User defines only two functions Map and Reduce. Map Task
is applied on a set of input data and produce ¡Key, values¿, the second function reduce allows to reduce partial results and

producing final ones.

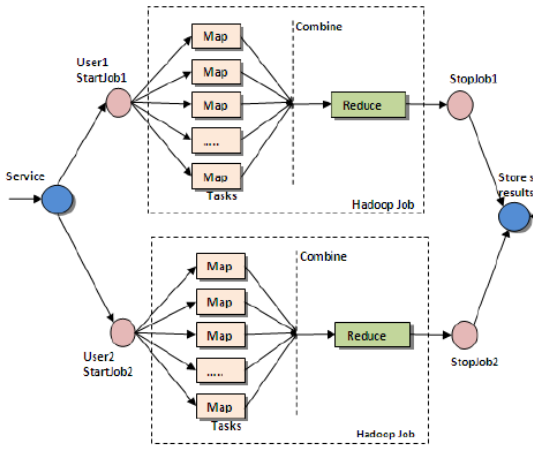

Fig. 1. Map Reduce

1) Hadoop: Apache Hadoop is an open-source Map Re- duce framework on clusters of commodity hardware. Hadoop
is an Apache top-level project being built and used by a global community of contributors and users.

The Apache Hadoop framework is composed of the fol- lowing modules:

- Hadoop Common contains libraries and utilities needed by other Hadoop modules.
- Hadoop Distributed File System (HDFS) a chunk based dis
- Hadoop YARN a resource-management platform re- sponsible for managing compute resources in clusters and using them for mapping and scheduling of users applications.[12]

Java is the used language with ”Hadoop Streaming” to implement the ”map” and ”reduce” parts of the user’s program. The Hadoop framework itself is mostly written in the Java, with some native code in C and command line utilities written as shell-scripts.

2) Hadoop Scheduler: Hadoop job schedulers are FIFO, and fair scheduler, not like FIFO scheduler fig 3, In fair scheduling, tasks not is the top of the queue, may be scheduled by assigning tasks into different pools, and assign to each pool, minimum guaranteed share. Figure 2 and
3 show the difference between both of FIFO and fair scheduler.

Each pool is characterized by the number of Map and
Reduce slots and the number of the maximum jobs assigned.

The scheduling algorithm is simple; first, it splits each pools min share among its jobs and split each pools total share among its jobs. When a slot needs to be assigned: If there is any job below its min share, schedule it. Else schedule

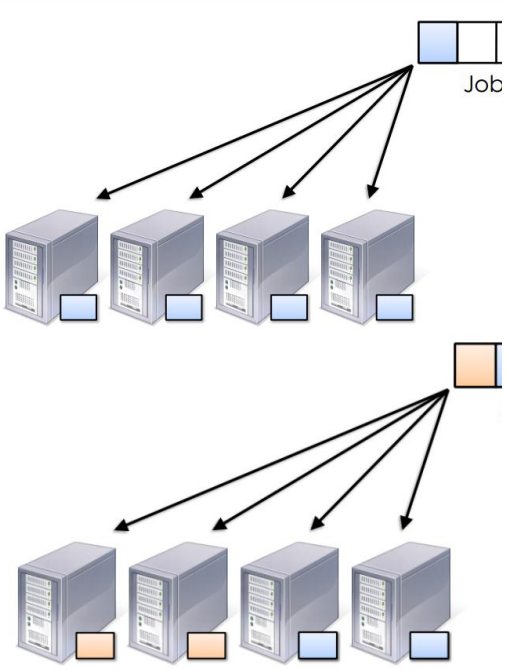

Fig. 2. Fifo and Fair scheduler

the job that has been most unfair to (based on deficit).Phan
et al in [6] explored the feasibility of enabling scheduling of mixed hard and soft real time map reduce applications. They tried to investigate the impact of some factors over the respect of time constraints such as data placement, concurrent users, and communication bandwidth.
The aim of the work of [6] is to use already existed scheduling real time algorithms on EC2 Amazon cloud. The tried to provide a scheduling algorithm to insure that hard real time tasks meet their deadline and try to satisfy soft real time constraints or at least minimize tardiness.
They focus on three points, what can affect the real time scheduling, based on results of the first investigation; they formulated the problem like a Constraint Satisfaction Problem CSP, the third step was solving the problem with a new heuristic for real time MapReduce tasks scheduling.

First they define parameters influencing real time schedul- ing as the number of map and reduce slots per a cote, multiple concurrent jobs, data placement, the interval of heart beats, and the algorithm of scheduling itself. Scheduling problem was formulated to a set of real MapReduce applications on
a distributed heterogeneous architecture as a CSP, which can be solved using well-known constraint solvers. They focused first on the offline setting, where the set of Map Reduce jobs are known a priori and the role of the scheduler is then to determine an optimal execution schedule for all tasks. The novelty of [] is that the formulation lies in the modeling of various factors unique to the Map Reduce jobs. Specifically, formulation considers slot-to-core ratio, the effect of input data placement on the data transfer time (from a remote or
a local host), and the interval based on heart beats between the master and the slaves. The last factor is the heterogeneity of the processors, where a tasks execution time varies based on the slots processing capability. The CSP formulation is based on very restrictive assumptions like:

each job contains no more than one map stage and one reduce stage. the worst-case execution time (WCET) of a task on each processor type is known a priori; all processors work perfectly without failure; and there is no speculative execution and no task migration.

The WCET assumption is necessary for real-time, they used WCET evaluator described in[9]. Gecode is the solver used to implement the formulated CSP. We can denote the absence of energy in the formulation, not only that but also the processor failure, which is a common thing in embedded hardware architectures. Using a solver is a high cost for problems like scheduling and mapping.

C. Hadoop for soft Real Time

Dong X et al in [1] have proposed an adaptation of Hadoop scheduler to support real time constraints, it allows to schedule mixed real time and no real time applications. The main contributions of this work are task forward scheduler and resources allocation model. The scheduler is compound of three sub-schedulers, Real time scheduler called deadline scheduler, no real time scheduler, and master scheduler that combine both. Thus allows reusing no real time schedulers. To grant real time constraints, they had used on line execution time evaluator proposed in [11]. One real time map and reduce job are picked randomly and submitted to sampling phase. The results of sampling phase are execution time for map and reduce task. The approximated calculated execution time is divided and added to correction values. Real time and no real time applications are queued equally, with a higher priority for real time applications.

Queued tasks are managed by deadline scheduler, and an existing no real time scheduler. If real time tasks cannot get needed resources, they can preempt some from non-real time tasks. In [1], The system assume

that the execution platform is homogeneous and all input data have the same size. The aim of the deadline scheduler is to maximize concurrent real time jobs on the minimum number of resources, and determine if scheduling a new task is feasible or not without influencing already scheduled tasks. Resource allocation modal aim to define the minimum size of parallelized real time jobs in order to maximize the number of concurrent real time jobs. Each cluster is composed by Map nodes, reduce nodes, real time map nodes, and real-time reduce nodes. A scheduled task assign query, by arrival time, relative deadline, the number of map and reduce tasks, execution time for each map and reduce task. The second step is defining the correct work load for each worker. It tries to make jobs as small as possible so the number of concurrent real time jobs is maximized. According to [1] defining the Degree of parallelism (work load) is optimal, and all the concurrent jobs have approximately the same size of by time unit. Jobs have the same size, execution platform homogeneous, the DOP is equal for all tasks, all these can be noticed as drawbacks and as restriction for this work. More, energy consumption and data load and delivery time impact is ignored.

D. Misco RT

Misco RT is a python implementation of Soft real-time Map Reduce. Unlike works discussed earlier, Misco RT runs on homogeneous embedded architecture architectures and it considers processor failures.

Misco architecture is simple, It comprises a Master Server and a set of Worker nodes. Server maps and schedules tasks on worker nodes, and keeps the execution tracks. The worker node is able to run even a Map and Reduce task. Each task
is characterized by the father application and the location of data (one input file), ready time, and real time characteris- tics. The Misco system is considered as a set of distributed applications A1, A2, .., An, compound of a set of Map and Reduce Tasks, applications are sporadic and their arrival time
is unknown a priori witch makes the system less predictable. The Master Server keeps track of user applications, while the Worker Nodes are responsible for performing the map and reduce operations. The Misco server also maintains the input, intermediary and result data associated with the applications, keeps track of their progress and determines how application tasks should be assigned to workers.

The main responsibility for the Misco worker is to process the individual map and reduce tasks and return the results to the server. The Misco worker consists of a Requester component,
a Task Repository component and a Logger component. The Requester is used for interactions with the Misco server to request tasks and download and upload data, trigger the local execution of the tasks, and handle the communication with the Misco system during upgrades. The Misco server is in charge of keeping track of applications submitted by the user and assigning tasks to workers. It comprises Scheduler that implements our two-level scheduling scheme, an Application Repository that keeps track of application input and output data, and an HTTP Server that serves as the main communi- cation between the workers and the Misco server.

Real time characteristics are defined by the user, and the execution time of an application depend on Map and reduce times and data load and delivery time. Misco RT applications and tasks scheduler is based on LLF, each calculated laxity is considered as its urgency. The main goal is not to reducing delays but maximizing the number of applications meeting their deadlines. However, this can cause a running failure because a dropped task will probably mean that all executed tasks of the same application was in vain.

Worker in Misco failure is permanent or transient. When a worker fails, all assigned tasks are lost. Server computes failure rate and redistributes failed tasks. Each free worker sends a request for jobs. Misco RT platform runs only on homogeneous hardware architectures, Misco platform is too much restricted, and run only on homogeneous hardware architecture, we denote also the absence of energy consumption especially for an embedded system like mobile phone, the reason for the platform was ever developed, we can notice the absence of a mechanism that insure the real time data transfer.

Real time applications are almost critical and data sensitive, however, few works had focus on the security aspect in map reduce environment, Roy et al in [12] have proposed a MapReduce environment with an enhanced security. Airavat
is a MapReduce-based system which provides strong security
and privacy guarantees for distributed computations on sensi- tive data. Airavat is a novel integration of mandatory access control and differential privacy. Data providers control the security policy for their sensitive data. Airavat confines these computations, preventing information leakage beyond the data providers policy. Airavat is modular and can be integrated to any map reduce platform. The prototype is efficient. Airavat will not be discussed in this paper just mentioned like a possible feature to complete limits of security for other Real time map reduce works.

III. CONTRIBUTION

The goal of our design is to provide more deterministic real time treatment and grant low energy consumption by exploiting the heterogeneity of the hardware architecture. Our system design is multilayer system, compound from 4 levels (fig 4)

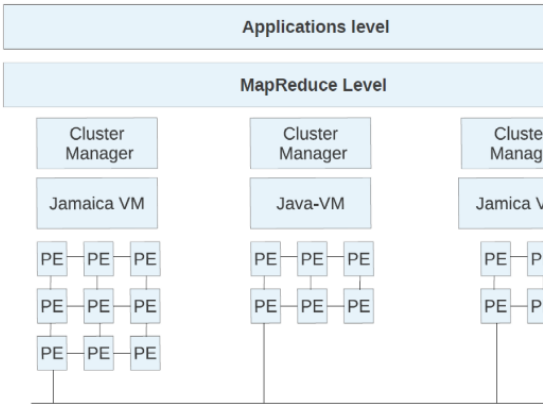

Fig. 3. Our design

Fig4. System design architecture

A. Application layer

In this layer the user defines each application by defining its map and reduce task with the real time characteristic (Type: Periodic or sporadic, Offset, Arrival Time, deadline) and data size, data location, splitible parameter witch define if a task can be spliced into subtasks to be run on parallel or not. MRID
is an integer that expresses the precedence order of a set of map tasks and one reduce task, semantically it means that the reduce task will reduce the results of that map tasks. And its defined automatically by the system. B. MapReduce Layer: It contains our main contributions. It consists of 5 entities, Real-time scheduler, requester, Data Splitter, Entities connection are shown in fig 6.

B. Scheduler

Applications scheduler is a fair scheduler with a maximum share per queue. Task scheduler is EDF (earliest deadline First) based scheduler, both of map and reduce tasks are sorted by deadline. In an obvious manor, Reduce tasks will be placed after the correspondent Map tasks (its deadline equals the deadline of the last map task plus its execution time). The second consist to give reduce tasks a better scheduling, because running the reduce task, mean concluding a set of processing,

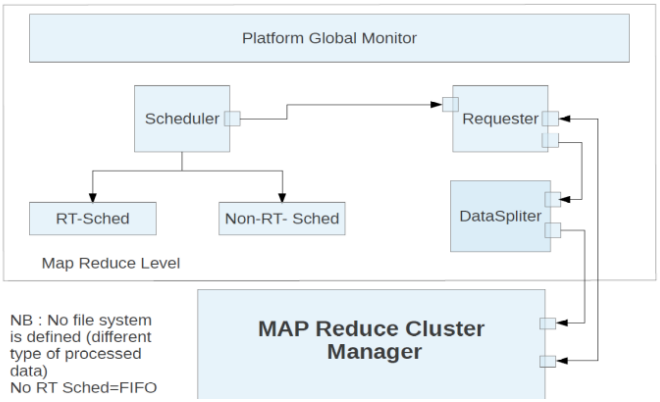

Fig. 4. Component connections

so free processors and memory. Each Reduce tasks then are higher priority than every Map task that does not equal to its MRID. Ready time for a Reduce task is computed, and not given by the user; it equals the last execution time for the last correspondent Final map task (see section data splitter).

C. Requester

It takes the scheduled task and sends a request to each processor in order to get free fits that corresponds between the arrival time and deadline of the selected task. It sends arrival time, deadline, and data size to each worker node. These lasts must reply by the executing fit. the execution rate, and the energy consumed if the map task will occupy that free fit. Each reply will be : (Processor, fit, execution rate, energy consumed). All replies will be sent to data splitter. The evaluation of the energy consumed and the execution rate will be discussed in section worker

D. Data Splitter

Compound from two levels, Solver and launcher. It takes the results of requester and tries to find the best solution that grant the execution of the task and the low consumption. The formulation of that problem is defined in formula 1.

A reasonable solution is a solution where the sum of rates equals or higher than 1. If a fit is considered then xi =1 else
=0. To exclude over running values we introduce the objective function min P. Minimize the energy consumed is the most important objective. The energy consumed depends on several parameters discussed in section worker.

$$\mathrm{MinE} = \sum_{} e_i * x_i$$

$$MinP = \sum p_i * x_i$$

$$\sum p_i * x_i \geq 1$$

To solve this problem, we use a branch and bound resolution method.

$$V + P_e * T_l * S_d$$

E. Worker

The worker is able to run both of map and reduce tasks, It contains three main modules, Load Evaluator, runner, and log register. a) Load Evaluator : It calculates the execution rate P and the correspondent consumed energy E based on data load time, data size, Worst case execution time, data delivery time. What we can execute in a fit equals:

$$P = \frac{e}{WCET + T_l * S_d * V} V * S_f$$

$$E = P_e * v^2 * S_d$$

$$S_f = P_e * \frac{WCET}{}$$

The Worst case load time and worst case execution time are not so deterministic values, so the monitors scale the computing speed to take benifit for unused inter fit space.

For simulation, we use SimSo simulator, It is an simulator for real time on multiprocessors uniform hardware architecture. Our approach stills in tests phases, and the final results will be published as soon as possible

IV. CONCLUSIONS

Our design can be easily plugged to Misco RT, or Hadoop, its modular and simple, however our design is for embedded hardware architecture like MPSoCs Based NoC, Hadoop is too much computational for such hardware architecture, Misco
is too much restricted, so we implemented our Map Reduce environment mainly in java with some native C code.

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Formal Approach for GPU Architecture Schedulability

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***Abstract*— Parallel application modelling and specifying is not an easy task to do because it treats tasks scheduling and time evolution. Graphics processing Unit is one of the main architectures that guaranties parallel execution. Event B is a skilled formal language based on sets theories. Our goal is to model and to specify the parallel execution of programs on GPU using Event B & RODIN platform. We are interesting to timing and scheduling of tasks on GPU.**

Key-Words : Parallel application, GPU, Formal specification, Timing, Scheduling, Event B.

I. INTRODUCTION

Parallel applications are the applications that can be divided into parts that can be executed in the same time. These parts do not depend on each other so they can be run simultaneously. Many-cores architectures permit to execute parallel applications thanks to its multiple processors. The Graphics Processing Unit (GPU) is one of these architectures and it is a puissant SIMD coprocessor (Single Instruction Multiple Data). The parallelism processing is granted by the big number of processing units on GPU. GPUs are used to improve applications execution such as multimedia applications and huge calculation applications. We call an application that is launched on GPU a kernel. This kernel is transformed into a grid of blocs. These blocs are divided into groups of 32 threads. When executing an application on GPU, we cannot see the different stages and the scheduling details. Modeling and specifying parallel applications is not a simple task to do. There are many tools to model this type of applications; one of them is formal methods. These latter are based on mathematic notions which make it sure and proved specification. Our goal is to model scheduling of kernel, blocs and threads and to propose a temporal model of tasks execution on GPU using Event B. The temporal model permits to show the time evolution when executing the tasks on GPU. Event B is a formal tool that allows us to create models and to validate it using automatic provers.

Event B does not support timing and scheduling of GPU tasks representation. Its mathematic bases permit to represent time evolution and scheduling process on GPU. Several works have dealt with time representation with Event B. Joris Rehm [1] has used Event B to model time constraints of the final step (root contention) of the distributed algorithm of the leader election protocol from IEEE 1394[2]. The proposed work consists of representing time and timers as additional variables of the system. They proposed to separate between the application model and the time constraints model so they refined the application model in a new model containing time evolution events. These events can be observed only when the system reaches a specific time which was named active time. This method was applied on several applications and it was also validated by Rodin in [3][4]. Another approach [5] was proposed to represent and to refine discrete time properties in Event B. They dealt with three main categories of discrete timing for trigger-response pattern: deadline, delay and expiry. These three kinds of timing constraints are used in many categories of time critical systems. For scheduling representation a set of works have treated it in Event B in different filed. The work of [6] proposed an approach to model concurrent scheduling. They presented an Event B model that covers the different interactions and concurrence of the famous problem of philosophers dinning through successive refinements. Another work [7] has dealt with modeling of event driven interaction in multi-agent systems. They have specified and proved interaction and scheduling between events using

Event B. In this paper, we propose a new approach to model timing and scheduling of tasks execution on GPU using Event B.

The present paper carries on in Section 2 by presenting Event B. Then, in Section 3 we introduce GPU architecture and scheduling on GPU. Section 4 shows the proposed formal specification of task execution on GPU and its scheduling and timing. Finally we conclude our work and we propose some perspectives.

II. EVENT B

Event B is an enriched extension of the formal method B created by J. R Abrial [8] for system specification, design and coding. It is based on Set theory and it specifies the system by abstract machines, operations and successive refinements which permit to prove, to verify and to validate the specified system.

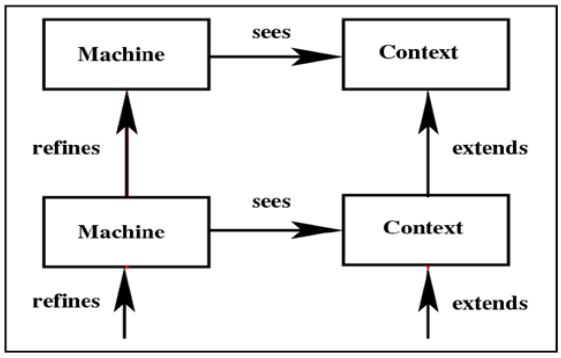

Fig.1 Refinements of models and contexts

Event B is based on MODEL notion which describes the labeled transaction of the system, named also machine in B method. A MODEL is composed of a static part which contains the states, its invariants and its properties and a dynamic part containing transitions (events). A MODEL has a name, variants, invariants and Events. A MODEL is completed by a formalism called the CONTEXT. It plays an important role in MODEL parameterization and instantiation. A CONTEXT has also a name, Sets, Invariants. [9][10] Each MODEL can reference a CONTEXT and many refinements which concrete models and contexts as it is shown in the figure 2. The Event B method is efficient because it uses tools like Atelier B[1] and the platform **RODIN** (Rigorous Open Development Environment for Complex Systems). This platform is a tool to develop and to prove Event B specification under Eclipse environment. [9] The main objective of RODIN is to create a methodology and supporting open tool platform for cost-effective, rigorous development of complex dependable software systems and services. [11]

III. GRAPHIC PROCESSING UNIT (GPU)

Graphic Processing Unit (GPU) is a puissant many core processor. GPU have a high performance processors dedicated to graphics processing. Originally, GPUs were oriented to accelerating graphics rendering functionality. Lately they are used to perform different kinds of general purpose computations in a parallel way to minimize application's runtime. [12]

A. *GPU Architecture*

GPU is a multi-core architecture used to enhance intensive computing and to discharge the CPU. A GPU is composed of a global memory and a set of Streaming Multiprocessor (SM). Each streaming multiprocessor is constituted of a set of Streaming Processor (SP) and each streaming processor is linked to a local memory (Register memory). And the SPs of a SM are linked to a shared memory. [13]

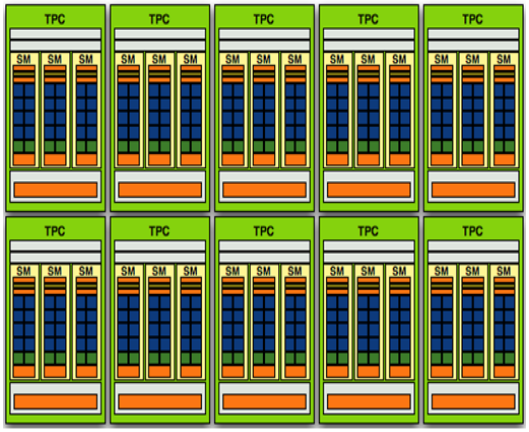

Fig.2 Nvidia GPU architecture

In Nvidia architecture, tasks are executed using SIMD (Single Instruction Multiple data) blocs written in CUDA. [14] CUDA (Compute Unified Device Architecture) provides a set of software libraries, an execution environment and a multitude drivers for different languages of programming (C,C++,…). CUDA is an extension of C language for programming on NVIDIA GPU. The computations on a GPU are programmed as *kernel* functions. A kernel program describes the execution of a serial *thread* on a GPU. The kernel is launched by the host CPU with specified numbers of blocs and threads, where a *bloc* represents a set of a certain number of threads, and all blocs in that kernel launch have the same numbers of threads. [13][14] The figure 3 shows the architecture of CUDA.

[1] Atelier B is a tool that permits operational use of the method B : http://www.atelierb.eu

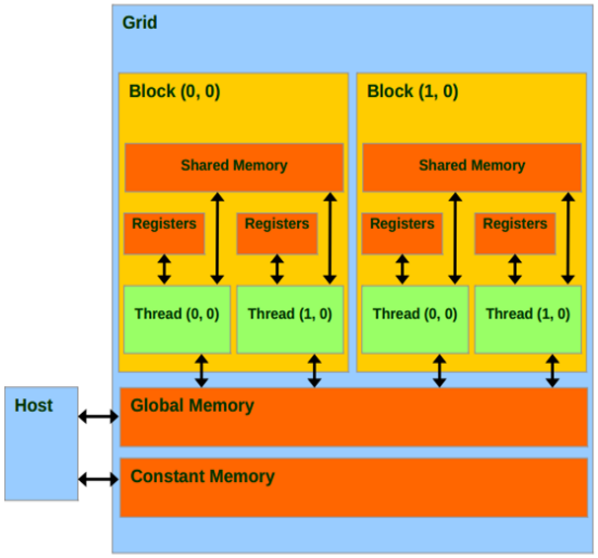

Fig.3 CUDA Architecture

B. *Scheduling on GPU*

Programs launched on GPU are called kernels. One kernel can be executed on a GPU in an instant. When a kernel is launched, it will be affected to a GPU and input data will be transferred from CPU Memory into GPU global memory. The kernel is represented by a grid composed of a set of blocs. Each bloc is constituted of a group of 32 threads. A bloc is executed on a SM of the GPU. If the number of available SMs on GPU is insufficient to execute all blocs in parallel, the blocs will be affected to free SMs and the reminding blocs will be added into a FIFO (First In First Out) waitlist. When a SM is liberated, the first bloc in the waitlist will be affected to this SM. In a bloc, the threads are executed in a parallel way in groups of 32 threads. The concurrence between the running threads of a bloc impact coherence memory (shared memory, global memory). In a bloc threads can communicate with each other using memory and synchronization barriers but threads of different blocs cannot be synchronized. When the grid finishes its execution, the result (output data) will be transferred to CPU.

IV. PROPOSED EVENT B SPECIFICATION OF TASKS EXECUTION ON GPU

In order to specify execution tasks on GPU, we propose an Event B model of kernel. This model is successively refined to show execution details. We have four levels: kernel execution, bloc scheduling, bloc execution and thread execution. A GPU context is added to define machines variables.

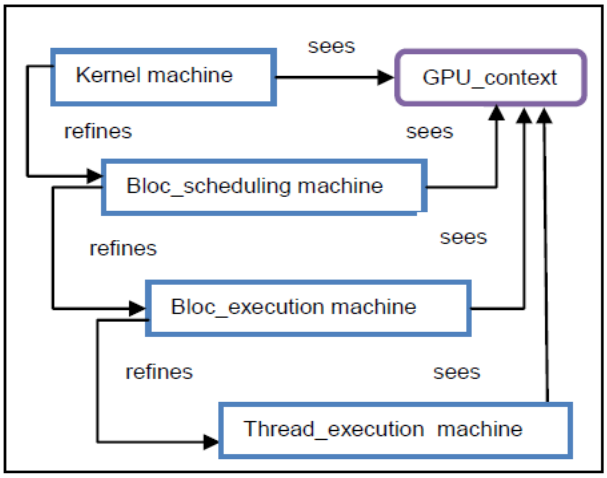

Fig.4 Elements of GPU executionspecification

A. *Basic model structure (kernel machine)*

The GPU kernel is defined by the variables:

- **nb_SM_GPU:** represents the number of SMs in the GPU of execution.
- **nb_kernel_threads:** represents the total number of kernel's threads.
- **Time_start:** represents the time of execution starting.
- **Time_end:** represents the time of execution end.
- **T_ev:** represents the time evolution.
- **GPU_OCC:** Boolean variable used to check if the GPU is free or taken.
- **K_state:** represents the state of kernel.
- **affect:** number of blocs.
- **nbreiter:** number of blocs according to the number of SMs on the GPU.
- **blocsArray:** a table that represents the blocs states.
- **blocs_start_time:** a table that represents the time of execution beginning of blocs.
- **blocs_end_time:** a table that represents the time of execution end of blocs.

The kernel machine has three events: waiting, execution and Endexecution. While the GPU is not free, the kernel waits.

WAIT ≙
WHEN
grd1 : GPU_OCC=TRUE
THEN
act1 : k_state:=wa ting
END

If the GPU_OCC variable is equal to false, the kernel will starts its execution. The value GPU_OCC will be changed to True and the kernel state will be "**executing".** To devise the kernel on blocs, the total number of threads is divided on 32. Then, the result is divided on the number of SMs on the GPU. This value defines the number of blocs that can be executed in parallel on available SMs of execution architecture (GPU). The T_ev

variable is incremented by c value, the time of division and affectation of blocs to SMs.

EXECUTION ≙
WHEN
grd1 : k_state=waiting
grd2 : GPU_OCC=FALSE
THEN
act1 : GPU_OCC:=TRUE
act2 : k_state:=executing
act3 : affect:=nb_kernel_threads÷32
act4 : nbreiter:=affect÷nb_SM_GPU
act : T_ev:=Time_start+c
END

The kernel finishes its execution when all the elements of bloc states are equal to end. So it liberates the GPU and save the time of execution end.

ENDEXECUTION ≙
ANY
m
WHERE
grd3 : m∈(0··nb_kernel_threads)
grd1 : k_state=executing
grd2 : blocsArray(m)=end
THEN
act1 : GPU_OCC:=FALSE
act2 : Time_end:=T_ev
act3 : k_state:=ending
END

B. Scheduling modeling

In the kernel machine, the kernel is divided into blocs of threads. These blocs must be scheduled to be executed on the available SMs of the executing GPU. To represent scheduling interaction in the kernel we proposed to use bloc state array (blocsarray). This array is modified in each stage of execution. Its dimension is the number of blocs calculated in the kernel machine. The values of the array's elements are initialized with "wait" in the beginning of execution. When the kernel is launched and divided into blocs the first 16 blocs will start there execution and there values in blocsarray is modified into "run". A table of 32 elements is created representing the threads states of the bloc, called threadsArray. When a thread is executing, it will change its state in the threadsArray table.

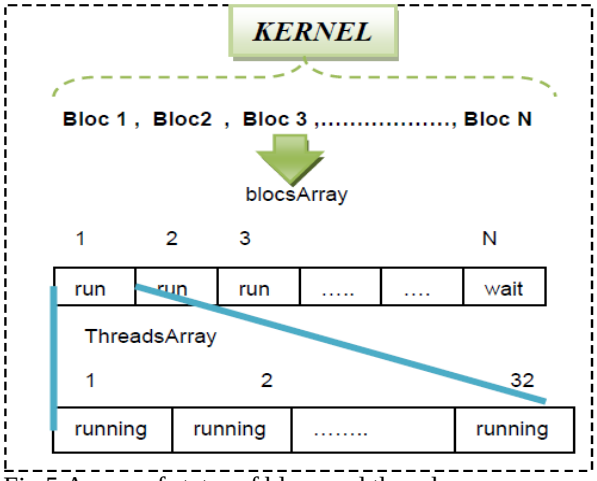

Fig.5 Arrays of states of blocs and threads

A bloc cannot liberate a SM until the 32 threads states are all equal to "finishing". So the bloc state will be changed to "end" and liberate the SM. These arrays permit the control and the evolution of parallel execution process. The kernel ends its execution when all the blocstates' elements are equal to "end", so it will liberate the GPU.

These arrays permit the control and the check of parallel execution process of the kernel, the blocs and the threads.

C. Timing modeling

To model time evolution, we proposed to use a variable (T_ev) that will be initialized by 0, then it will be incremented. To calculate blocs and threads timing we used tables for saving starting time execution and ending time execution. T_ev is incremented in kernel machine by the duration of kernel decomposition (c). When the kernel is launched the elements of blocs_start_time array will be initialized by T-ev (T_ev=c, in the beginning of bloc execution). blocs_time_end array also is initialized by T_ev. If a bloc starts its execution, two tables of 32 elements will be created called (threads_start_time, threads_end_time).

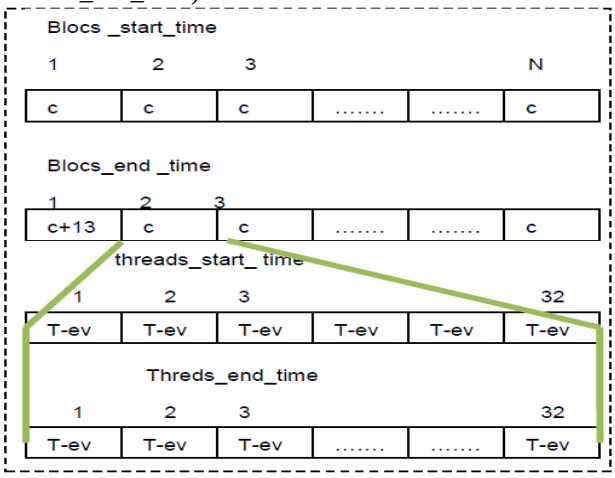

Fig.6 Arrays of timing of blocs and threads

The two arrays threads_start_time, threads_end_time are initialized by the value of

bloc_start_time. When a thread starts its execution, the duration of this latter will be added to strat_time_thread. If the thread needs access to global memory and this latter is not accessible, the time of waiting is added to its runtime until getting access to memory. When all threads of a bloc finish there execution, the maximum of the threads_end_time of the 32 threads is affected to bloc_time_end of this bloc. The maximum of end_time_blocs is affected to T_ev and this latter is the runtime of the kernel.

D. Refinements of the basic model

D.1 *Bloc_scheduling machine*

When the kernel execution is launched, the first 16 blocs will be affected to the available SMs (16 in our GPU). So there states will be changed into "run". There states and there starting times are initialized in the Affectation event.

Affectation ≙
WHEN
grd2 : j<k
THEN
act4 : current_bloc≔j−(nb_SM_GPU+1)
act1 : blocsArray(j)≔run
act2 : blocs_start_time(j)≔T_ev
act3 : j≔j+1
END

After having launched the sixteen blocs execution, the rest of blocs are all waiting for an SM to liberate.

When a bloc is in state run, a table of 32 elements is created, it is called threadsArray.

D.2 *Bloc_execution machine*

When a bloc is affected to a SM and its state is changed to "run", it creates the threads-state and the timing arrays. These arrays are initialized in the event bloc_executing. The threadsArray elements are initialized with "ready".

bloc_executing ≙
ANY
M
WHERE
grd1 : m∈ℕ
grd2 : blocsArray(m)=run
grd3 : pointeur1≤32
THEN
act1 : threadsArray(pointeur1)≔ready
act2 : pointeur1≔pointeur1+1
END

When a bloc is in execution, the threads are running in parallel. Some threads can finish there execution and the others can't. So there is a verification event that verifies the execution end and saves the runtimes of the threads in a Time Set.

bloc_ending_verification ≙
ANY
m
WHERE
grd1 : m∈ℕ
grd2 : blocsArray(m)=run
grd3 : pointeur2≤32
grd4 : threadsArray(pointeur2)=finishin
THEN
act2 : TimeSet≔TimeSet∪{threads_end_t
: (pointeur2)}
act3 : pointeur2≔pointeur2+1
END

When all the threads of a bloc finish there execution, its blocsArray value is changed to "end" and the maximum of threads execution is affected to its bloc_end_time.

bloc_ending ≙
REFINES
verifying_execution_end
ANY
m
WHERE
grd2 : m∈ℕ
grd1 : blocsArray(m)=run
THEN
act1 : blocs_end_time(m)≔max(TimeS
act2 : T_ev≔max(TimeSet)
act3 : blocsArray(m)≔end
END

D.3 *Thread_execution machine*

When a thread is created, it is initialized with the state "asleep". If its dominant bloc is activated, the thread state is modified to "ready" state and its starting time is initialized. This step is represented by the election event.

Thread_election ≙
ANY
m
WHERE
grd2 : blocsArray(m)=run
grd1 : threadsArray(pos)=asleep
THEN
act1 : threadsArray(pos)≔ready
act2 : threads_start_time(pos)≔T_ev
act3 : threads_end_time(pos)≔threads_
: start_time(pos)
END

When the threads are running, they need access to global memory. This access could be happen in the same time, so we propose to use a variable that controls the access memory. The thread is waiting while the global memory is inaccessible. This thread's execution time is incremented by the time of waiting.

Thread_waiting ≙

WHEN
grd1 : threadsArray(pos)=ready
grd2 : MGA=notaccessible
THEN
act1 : threads_end_time(pos):=threads_s s)+1
END

When the memory becomes accessible, the thread passes to the "running" state and it will be executed. The duration of its execution is added to its thread_end_time value.

Thread_running ≙
WHEN
grd1 : threadsArray(pos)=ready
grd2 : MGA=accessible
THEN
act3 : MGA:=notaccessible
act1 : threadsArray(pos):=running
act2 : threads_end_time(pos):=threads_end_time(pos)+duration
END

When the thread finishes its execution, it liberates the global memory and modifies its state to "finishing".

Thread_finishing ≙
WHEN
grd1 : threadsArray(pos)=running
THEN
act1 : threadsArray(pos):=finishing
act2 : MGA:=accessible
END

V. CONCLUSION

In this paper we proposed a formal specification of GPU tasks execution using Event B language. The proposed specification models the Nvidia GPU's programming model. The programming model of a GPU consists of executing kernels in the form of grids composed of blocs and these blocs are composed of threads. This organization has been specified using successive refinements of the basic model which is the kernel in Event B using Rodin platform. In our specification, we tried to model the scheduling on the GPU and the timing of each component (kernel, bloc, thread). Another aspect was treated which is the access memory concurrence. The complexity of our specification is measured by the number of proof obligations which are automatically/manually is charged (see table 1).

Model	Total	Auto	Manual
Kernel	25	15	0
blocks_scheduling	22	12	0
Block_execution	38	18	0
Thread_execution	17	10	0
Total	102	55	0

Tab .1 Summary of proof obligations

We remark that automatic proofs changes from a model to the other, in the bloc_execution model there are more proofs that are not handled by Rodin provers. We didn't used the manual proofs or import hypothesis to discharge obligations proof to see the correctness of our specification.

As a part of our future works, we aspire to model specific parallel applications such as matrix multiplication and image processing on different GPU's architectures by refining our proposed basic Event B specification. Another perspective is to generate a valid executable code in CUDA and OpenCL from the Event B specification of parallel applications

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Based refinement Verification platform for QNoC Architectures

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***Abstract*—Formal models play an important role of the requirements that lead to models of the design for a network on chip which is a reconfigurable FPGA-based (Field Programmable Gate Array) technology for faulty tolerance System-on-Chip, where the main challenge was how to achieve a conceptual design of multiprocessor System On Chip (MPSoC). The use of formal methods with the progressive basis and the proof theory has become an essential step to design and validate this architecture. Event-B is a formal modelling language, which supports refinement as a based-formal concept of development to models and proves the industry of MPSoCs. The purpose of this article is to provide a formal verification of Network-On-Chip (NoC) architecture using the Event-B method. This process is delivered by a correct and validated formalization based on the correct-by-construction development approach.**

***Index Terms*—Network on chip, Switch, Adaptive-routing, machine, context, Model, specification, refinement, Formal proof, Correct-by-construction, Active Zone.**

I. INTRODUCTION

Formal methods have the ability to produce critical systems for large industrial projects, and this by creating an original mathematical model that can be formally refined in levels until the final refinement that contain enough of details for an implementation. Before the verification simulation does not allow the detection of all possible design errors [1]. That's why we use the formal methods Event-B in our work, and in particular the correct-by-construction paradigm [2, 3] to specify hardware systems. The paradigm correct-by-construction offers an alternative approach to prove and define correct systems and architectures, for the reconstruction of a target system using progressive refinement and validated methodological techniques [4]. Our goal is to complete the simulation time in the design flow with a formal proof method. The preconditions for the formal development of microelectronics architecture are given the description and /or design of the architecture.

The large amount of work has focused on the use of formal methods to verify communication systems and protocols. Most use model-checking, or its composition with proving theorems. The work of Clarkeet al, published in [5] to check the temporal properties of parameterized ring networks and binary tree. A first step is to use a free-context grammar to models network communication systems when temporal properties are verified using a model checker. In [6] Amjaduses a model checker implemented in HOL to verify AMBAAHB protocols and PDB. Bharadwajet al. satisfies a broadcast protocol in a binary tree network using the SPIN model checker demonstrator and Coq [7]. In [8] Curzondevelopsa structural model of ATM switch Fairsile and compares its behavioral specification using HOL. The free deadlock in the network Ae the real was verified by Gebre Michael and al. Using the PVS tool [9] Some studies based on semi-formal methods were also proposed. They essentially designed to detect and debug failures. Chenard and al proposed in [10] include assertions listeners PSL [11] synthesized using NGC tool [12] in a network on chip. Analytical approaches do not carry out of the dynamic

behaviour and performance of a system, but to analyze it statically. Model checking is an automated technique to verify each models of a system satisfies its specification.

[13] The model is described in a kind of state machine and the specification is described in a temporal logic. A model control algorithm uses the transition function associated with the state machine to explore the state space and define States that do not meet the specifications. If finds is a state, the state and the trace leading to this state are reported. If such a state is not found, the system is proved correct. Model checking is widely adopted by universities and industry, primarily because it is fully automatic and can provide against-examples. The major problem is a combinatorial blow-upin the number of states that must be explored, called state space explosion. This severely limits the scalability of model checking. Theorem proving is a technique where the evidence of a mathematical theorem is formalized so that a computer program can guarantee their accuracy. The main advantage of the theorem is the ability to deal with the parametric systems.

The aim of this work is the verification of SoC communication [14] describes the main challenges in the design of NoC [15] and discusses some aspects of audit networks or formal methods are useful. The dynamic reconfigurable NoC are adequate for FPGA-based systems, where the main problem arises when IP (intellectual property) components must be at run time defined dynamically. Given the rapidly changing and highly complex MPSoCs (multiprocessor system-on-chip), the constraints related to the complexity and the increasing number of interconnected modules or IP such as the cost and performance must be resolved. Current communication networks on chips implement the data transmission between the interconnected nodes. Sometimes the communication of this kind of networks is difficult or even impossible. This is the main reason why XY fault-tolerant routing algorithms (such networks) have been established. [16] Routers can control the miss-routing of previous detectors (eg packet on the path XY, etc). In addition, new techniques and adaptive faulty-tolerance routing with error detection and path routing based on the well-known XY model, have been introduced.

Formal studies have focused on NoC performance [17,18], latency [19], bandwidth [20], the estimation of consumption[20], detection and error correction[21,22], and the surface are used. Others propose methods of free-deadlock routing [23, 24] to characterize the traffic. [25] In this article, we use Event-B to specify, verify and demonstrate the NoC behavior. The paper is organized as follows. Section 2 presents an overview of the Event-B method. Section 3 presents the NoC architecture studied with the audit results of the verification Formula. Section 4 describes the architecture of the faulty tolerance. Section 5 Model description and we concludes this paper with future works

II. EVENT-B

The Event B modeling language can express safety properties [26], which are invariants, theorems or safety properties in a machine corresponding to the system. Event B allows a progressive development of models through refinements. The two main structures available in Event B are:

- Contexts express static information about the model.
- Machines express dynamic information about the model, invariants, safety properties, and events.

An Event B model is defined either as a context or as a machine. A machine organizes events (or actions) modifying state variables and uses static information defined in a context. The refinement of models provides a mechanism for relating an abstract model and a concrete model by adding new events or variables. This feature allows to develop gradually Event-B models and to validate each decision step using the proof tool. The refinement relationship should be expressed as follows: a model M is refined by a model P, when P simulates M. Thus, from a given model M, a new model P can be built and asserted to be a refinement of M describing the architecture. Model M is an abstraction of P, and model P is a refinement (concrete version) of M. Likewise, context C, seen by a model M, can be refined to a context D, which may be seen by P. The final concrete model is close to the behavior of real system that executes events using real source code. The relationships between contexts, machines and events are illustrated by the next diagrams, which consider refinements of events and machines. The refinement of a formal model allows us to enrich the model via a step-by-step approach and is the foundation of our correct-by-construction approach [27]. Refinement provides a way to strengthen invariants and to add details to a model. It is also used to transform an abstract model to a more concrete version by modifying the state description. This is done by extending the list of state variables (possibly suppressing some of them), by refining each abstract event to a set of possible concrete versions, and by adding new events. In fact, the refinement-based development of Event B requires a very careful derivation process, integrating possible tough interactive proofs for discharging generated proof obligations, at each step of development.

Event B also is supported by a complete toolset RODIN [28] providing features like refinement, proof obligations generation, proof assistants and model-checking facilities. Rodin Platform tool, called Proof Obligation Generator, decides what is to be proved in order to ensure the correctness of the model. Moreover, it is now being improved and extended by other "plug-ins" [26].

III. ARCHITECTURE DESCRIPTION

A QNoC Switch (see Figure 1) [29] consists of routing logic and control logic with inputs / outputs each direction. This micro-electronic architecture communicates with four neighboring elements.

The computing elements associated with the NoC network communicate through messages. A message consists of a fixed number of packets.

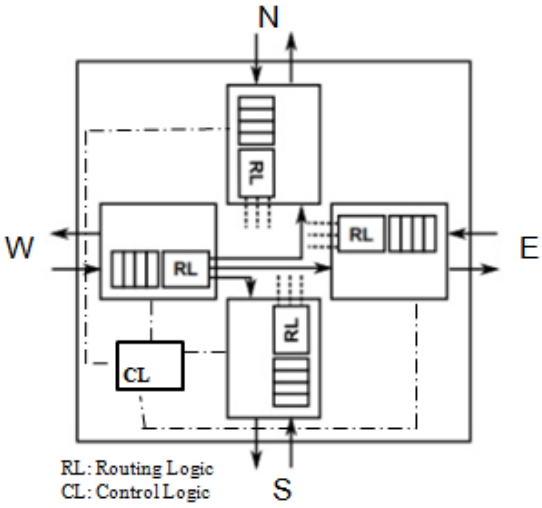


Fig.1. QNoC Switch

An incremental development of a Network-on-chip Architecture using the event B formalism. [25] The formalization of the architecture is presented from an abstract level to a more concrete level in a hierarchical way.

The first model ***xyM0*** is an abstract description of the service offered by the NoC Architecture: the sending of a packet (p) by a switch source and the receiving of (p) by a switch destination.

The machine xyM1 refines ***xyM0*** and introduces a network (*a graph*) between the sources and destinations of packets. Some properties on the graph are defined in context ***xyC1***: graph is non-empty, non-transitive and is symmetrical.

The second refinement decomposes the event FORWARD of ***xyM1*** into two events:

- A refinement of the event FORWARD depicts the passing of a packet (p) from a switch (x) to a channel (ch), leading to a neighbour (y).
- An event FROM_CHANNEL_TO_NODE models the transfer of a packet (p) from a channel (ch) to a connected switch (n).

The third refinement allows us to introduce the structure of a switch gradually. We express, in xyM13, that switches possess output ports.

The fourth refinement (xyM14) adds input ports to the structure of a switch.

The fifth refinement introduces the storage of packets in a switch: each output port of a switch can store a number of packets up to a limit (outputplaces) of three messages. Packets can be blocked in a switch, because of the "wait" or "occupation" signals from neighbours. The event SWITCH_CONTROL is refined, and adds the fact that following the transition of a packet from an input port of a switch (x) to an output port, if the switch (x) is not busy anymore, it sends a release signal to the previous switch linked to the input port. A new event RECEIVE_BUFFER_CREDIT models the receiving of a release signal by a switch (n).

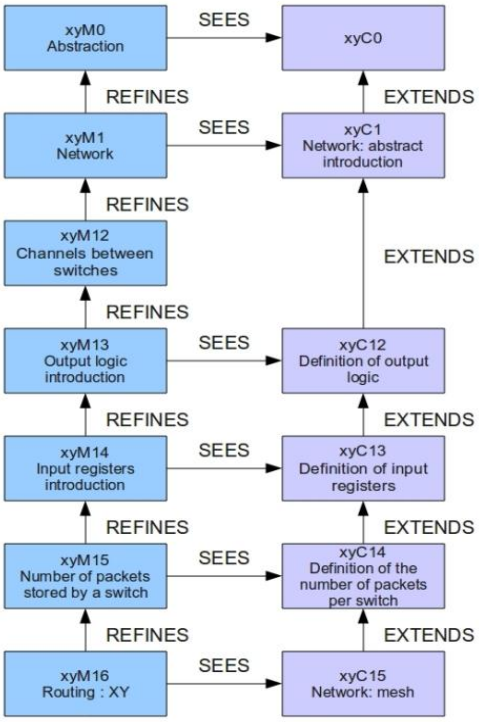


Figure 5. *Step-by-step Modeling of NoC Architecture*

The last model xyM16 describes the architecture of the network (graph): graph has a mesh topology (see Figure.12). A numerical limit (nsize) is introduced to bound the number of routers in the dimensions x and y of the network topology; the network will be a regular 2D-Mesh, with a size (nsize _ nsize); each switch is coupled with unique coordinates (x; y), with x 2 [0::nsize 1] and y 2 [0::nsize 1].

IV. Fault Tolerance

A. The adaptive routing algorithm

The Switch produced in stating that packets are routed along the X axis then to the Y-axis direction of the network. If in the routing packets encounter modules that prevent them to go through the traditional way then the routing algorithm used allows circumvention with the control logic for each router distinguishes the entity type (router or calculation module) connected to a router. So this algorithm avoids deadlock situations that may happen in the QNoC and also solves the problem of packet arrival at a network node order. Indeed, if during operation of the network, there is no dynamic investments between two compute modules, the paths taken by packets sent from one module to another recipient module will be identical and of the same length (same position as the algorithm XY), while maintaining the order of transmission and reception of packets. As against, the packets of a message sent by a calculation module, can be nested to the destination with the packets of other messages sent from other computing modules in

the network. Uses a routing algorithm based on the classical XY algorithm that can be used initially in the reconfigurable network because it is not suited to irregular situations.

B. definition

A disabled network region is the rest of the network not belonging to the active area.

If a network does not have an activated area (no faulty nodes or regions), it is fully disabled. All nodes belonging to the disabled area are disabled.

If there is a network in an active region formed around a failed node. In this case, only the routing nodes surrounding the failed node routing change status and become activated. The nodes belonging to the rest of the network do not change their way and remain disabled.

A deactivated node routes a data packet according to the XY algorithm. First, it routes the packet according to the X axis and then along the Y axis until the data packet is not delivered to the destination. If the packet arrives to the activated before reaching its final destination area, new routing rules are then applied.

The activated routing nodes do not obey the same rules as routing nodes routing disabled. These rules are described as follows [29].

Rule 1: A peer and activated node cannot route packets from the North (North) to the East (East) and vice versa.

Rule 2: An odd and enabled node cannot route packets from the southern direction (South) to the West direction (West) and vice versa.

Rule 3: All nodes enabled by default, cannot route packets from each of the north and east directions to the south and west directions.

Rule 4: All nodes are not activated by default route packets from respectively the South and West directions to the north and east directions.

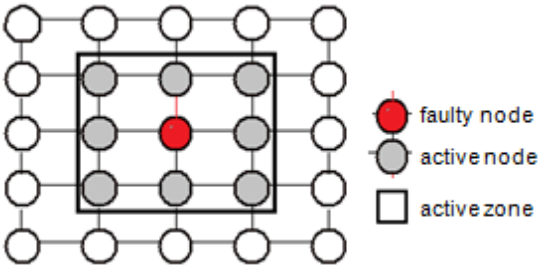
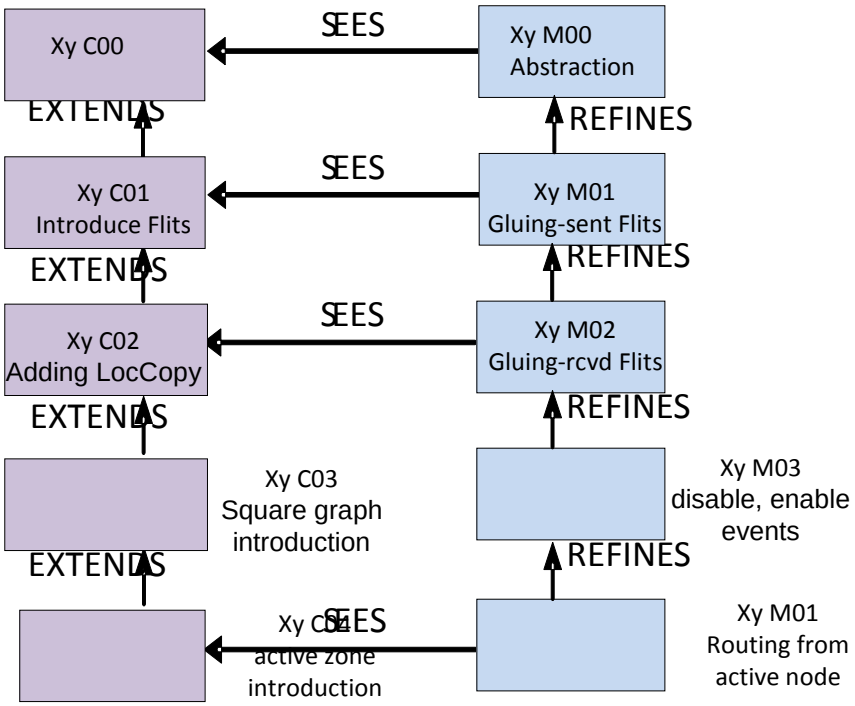


Fig.3. *Exemple d'une zone activée.*

Since a message is broken into packets, which are also broken down into conflicts, then we can rewrite the rules as follows:

- A flit of a packet that is in the active region may circulate in the x-axis and not in the Y axis;
- A flit of a packet that is in focus can move from north to west but not east;
- It can be routed arriving from South to East not west.



V. MODEL DESCRIPTION

The formal development of the fault tolerant routing scheme of the considered NoC Architecture. This proving formal is based on refinement which allows breaking the operation complexity of the routing algorithm and performing this formalization with different levels of abstraction carried out step-by step **[11]**. Fig.5 presents the step-step modeling of the proposed fault tolerant routing scheme.

Fig. 5. Step-by-step Modeling of fault tolerant routing algorithm suitable for NoC.

The abstract level defines the role of the network to send an infinite number of messages which are packetized and encapsulate (*Flitization*) into sequence of packets from a source (S) to a destination (D).

The machine ***xyM01*** refines *xyM00* and introduce cutting packets on flits (**xyC01:** FLITS is new set introduced by this context, cutting each packet on flits (axm1), and the flits of each packet are different from those of other packets (axm2)

The second refinement add LocCopy variable, this variable (in the context; the local copy of the package is in the original sources, and in the sources of these packages, and Theorem which states that the local copy are originally in one place on the network).

xy M03 a refinement of the behavior of a node in case it is broken and when it returns to normal is expressed in both disable and enable events. This level also allows us to create the variable locCopy to ensure flits sends a packet without losing

disable node is a node *n* becomes faulty / off: it can no longer receive or route messages of its neighbors, the new graph *new-gr* will be the current without bidirectional links between the node n and its neighbors, however Enable is a node n becomes active: it can again receive and route messages from its neighbors when n no longer part of the current graph, gives n in the current graph with bidirectional links with his former neighbors.

Xy C04: introduction of operators for calculating the active zone surrounding a knot near faulty zone. The rectangle given by z (a) and including a contains n nodes whose coordinates (x, y) are defined as: LimXmin(a) $\leq x \leq$ *LimXmax(a) et LimYmin(a)* $\leq y \leq$ *LimYmax(a)*

Xy M04: This machine contains a refinement of two events

- The routing flits in different directions depending on the destination:

If after the node (s) is transmitted flit (f) to the node (y), (x) still has flits of f, the local copy does not change and x no longer has flits of f, the local copy of p changes from x to y. This is expressed in the following warning:

VI. CONCLUSION

B-event method is a formal method for the development of computer systems, the accuracy must be formally established.

The proofs of QNoC architecture did not need tough efforts (neither importing hypotheses or simplifying goals, etc), the mere usage/ running of provers (provided by RODIN platform) allowed us to discharge these obligations. Contrary to the verification by simulation only, our work provides a framework for developing the Network-on-chip architecture and the XY routing algorithm using essential safety properties together with a formal proof that asserts its correctness.

Our experience shows that many models still contain proven breaches of etiquette, which are detected with a facilitator or a model checker. In addition, although the proof obligations for the absence of deadlocks are provided in Event-B, they are not yet implemented in RODIN. The reason is that the proof obligation in the form of a large disjunction (the disjunction of the guards of all events), which is often very difficult to prove.

It has been found with the Plug-in PROB that this strategy may be applied to the network if they are part of the active area. In the future other strategies will be adopted to this critical situation, we need to formally prove their

A new adaptive routing algorithm based on the rules of circumvention, and improved by a routing strategy. Developed and integrated into a network on chip (RKT-Switch). Implemented on FPGA

Rodin is a platform to edit, animate, and prove-prove against models in an integrated way.

By detecting problems in a model that are not covered by the proof obligations (such as deadlock or other unexpected behaviour). It has been found with the Plug-in PROB that this strategy may be applied to the network if they are part of the active zone. In the future other strategies will be adopted in this critical situation, A new adaptive routing algorithm based on the rules by pass is improved by a routing strategy, developed and integrated into a network on chip and implemented on FPGA.

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Authentication and identification of individuals from the iris images

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***Abstract*— In this paper, we present an efficient method that allows us to authenticate and identify individuals by using iris images. In fact, the proposed method consists of three main steps. In the first step, we segment the image in order to define the upper and lower parts of the eyelids. We use two segments to exploit efficiently the region of interest of the iris and to extract only the interior half of the iris disc, which contains the most discriminate information. In the second step, the iris image is normalized by Daugman rubber sheet model, and then analyzed by bench of two 1D Log-Gabor filters to extract the texture characteristics. For the authentication and the similarity measurement between two irises, we use the Hamming distance with a threshold previously calculated. We then propose for the identification mode, a classification method based on the Multi-class SVM adopting the approach one against one. The proposed method has been tested on the Casia v1 database (756 iris images). For the authentication mode, we obtain very encouraging results: 1.39% for the global FAR, and 4.45% for the global FRR. For the identification mode, we obtain a rate recognition equals to 98.61%.**

Keywords- Authentication; identification; recognition; iris; classification; Multiclass SVM.

I. INTRODUCTION

Identification by biometrics give us the possibility to recognize or check the identity of individuals, with a high degree of reliability. Currently, the use of the biometric systems such as recognition by the iris, face or by the fingerprints is of widespread interest in many environments of high security like the nuclear plants, the banks… etc.

The biometric systems that based on recognition of the face or the fingerprints are widely employed by the users; however, these systems cannot guarantee a very high security level comparing to a biometric system based on the iris. In addition, recognition by the iris characterizes by a very low error rate, where the probability to find two identical irises is 1/1078 proved by Dr. J. Daugman, and its stability is extended until death of the individuals. In fact, iris recognition system is one of the most successful systems that used for identifying individuals [1].

However, identification of individuals using the iris has several problems that are not completely resolved, such as, the localization of the iris in an iris image, the analysis and the characterization of the iris texture.

Currently, many researchers work on these problems, and the suggested methods are distinguishable from each other by the used techniques in the phases of segmentation, analysis and characterization of the iris. For iris segmentation, two methods are usually used: the intégro-differential operator [2] and Hough transform [3] [4] [5] [6] [7] [8]. For iris characterization, the most used methods are Gabor wavelet transform applied by Daugman, [3], Laplacian pyramid [4], packages wavelet transform [9] [10], multidimensional Hilbert transformation [5]. Recently, Khiari and Al [6] proposed another method based on the application of the directional pyramidal transformation.

In this paper, the key idea was inspired from the work of L. Masek [7], which developed iris authentication system that follows these main steps:

- Segmentation based on circular Hough transform to delineate iris and pupil circles, and linear Hough transform to define the high and low parts of the eyelids.
- Normalization step was applied to compensate the non- concentricity of the two borders and the varying size of the iris caused by the dilation/contraction of the pupil.
- A bench of two 1D Log-Gabor filters is used for extracting information from iris texture, and then the encoding was realized

with a phase of quantization developed by J. Daugman [11].

In fact, this work presents two main contributions related to iris segmentation phase. First, we define the upper and lower parts of the eyelids by two lines segment in order to exploit efficiently the region of interest of the iris. Second, we consider only the interior half of the iris disc that contains the most discriminate information, and it is less affected by noise. In addition, we develop an iris identification system by using a classification method based on the Multi-classes SVM relied on the approach one against one.

The remainder of this paper is organized as follows. The iris pre-processing and characterization is presented in section II. The authentication mode is devoted in section III. The identification mode is detailed in section IV. Finally, conclusions are drawn in section V.

II. IRIS PRE-PROCESSING AND CHARACTERIZATION

A. Iris segmentation

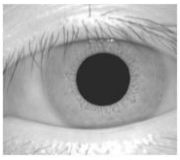
Iris segmentation consists in the extraction of the iris disc delimited by the circular borders of iris/sclera and iris/pupil.

Thus, detection of these boundaries in our system is based on circular Hough transform, which needs at the first time to the generation of an edge map. In this context, a modified version of Kovesi's Canny edge detection function [20] was applied, which allows the weighting of the gradients.

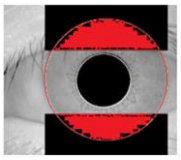
In our work, only vertical gradients are employed to detect the external circle of the iris disc, while vertical and horizontal gradients are both weighted to detect the points of the iris/pupil circle as proposed by Wildes [12].

The detection of the external border of the iris/pupil is firstly performed by applying circular Hough transform only in the iris area, instead of the whole area of the eye. Afterthat, we obtain the rays, and the centers of the two circles delimiting the iris.

For separating the eyelids, we firstly used a simple thresholding technique. The analysis reveals that eyelashes are quite dark compared to the rest of the eye image. The obtained results show some anomalies that appear by the unexploited areas marked with red color, as illustrated in Figure. 1.

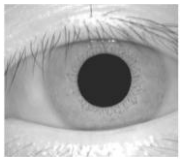


Original image.

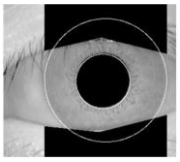


Segmented image (1).

To deal with such problem, we chose another technique for delimiting the high and low eyelids with two segments by using linear Houhg transform [13], as shown in Figure. 2.

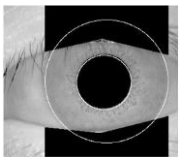


Original image.

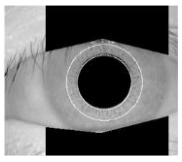


Segmented image

information, which is represented by the structural variations of the iris texture (high gradient areas), we preferred to exploit only the internal half of the iris disc, because it contains the most discriminating information and it is less affected by the noise (eyelids), as shown in Figure. 3. Indeed, the proposed technique decreases the complexity and the computation load without losing information.



Segmented iris (2)



Segmented iris (3)

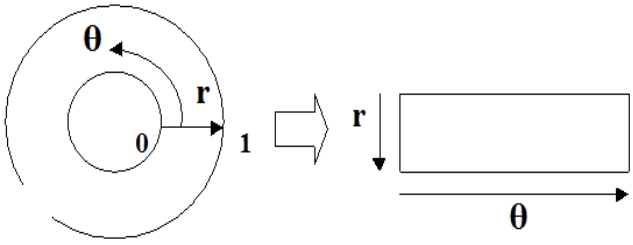
Figure 3. Location of the structural change of the iris texture.

B. Iris normlization

The iris disc does not always have the same dimension, even for eye images of the same person; this is due to various problems as follows:

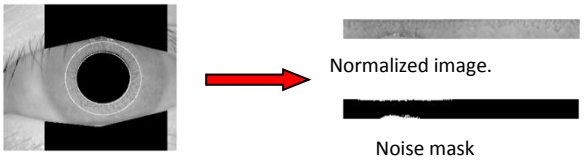
- Different acquisitions conditions of the eye images.
- Dilation and contraction of the pupil due to the variation of the illumination level.
- The pupil region is not always concentric within the iris.

In order to overcome these problems and to compare between different segmented iris images, a stage of normalization is applied. It consists in transforming the region of the iris disc to rectify the dimensions of all the iris discs, by using the homogenous rubber sheet model proposed by Daugman [11]. It transforms each point in the iris area to the polar coordinates (r, θ), where *r* is on the interval [0,1] and θ is angle [0,2π], as illustrated in Figure.4.



Daugman rubber sheet model [11].

ır system, we use (20*240) points, but only) points corresponding to the internal half s disc that are retained for the next steps of essing, as shown in Figure. 5.



Normalized image.

Noise mask

Segmented image (3).

Figure 5. Normalization of the segmented iris.

The remapping of the iris region from (x,y) Cartesian coordinates to the normalized non-concentric polar representation is obtained by the equation (1).

$$x(r,\theta) = (1-r) \times x_p(\theta) + r \times x_i(\theta)$$
$$y(r,\theta) = (1-r) \times y_p(\theta) + r \times y_i(\theta) \quad (1)$$

Where (x,y) are the original Cartesian coordinates, (r,θ) are the corresponding normalized polar coordinates, (x_p,y_p) and (x_i,y_i) are the coordinates of the pupil and iris boundaries along the θ direction.

C. Iris Extraction parameters and encoding

Once the segmentation and normalization process are achieved, the next step is the extraction of the most discriminating information present in the iris region. For this reason, we apply the following steps:

- We first applied for each line of the normalized matrix image the Fast Fourier Transform (FFT to 1D signal).
- We then applied the Inverse Fast Fourier Transform IFFT on the multiplication FFT (1D signal) by a 1D Log-Gabor Filter.

The frequency response of a 1D Log-Gabor filter is given by:

$$G(f) = \exp\left(- \frac{(\log(f / f_0))^2}{2 \times (\log(\sigma / f_0))^2} \right) \quad (2)$$

Parameters setting :

- We used a bench of two 1D Log-Gabor filters.
- The bandwidth of the 1D Log-Gabor wavelet is given by $\sigma / f_0 = 2$.
- Center frequency of the 1D Log-Gabor wavelet is given by $f_0 = 18$ pixels.
- One of the disadvantage of Gabor filter is that the even symmetric, filter will have a DC component whenever the bandwidth is larger than one octave [14]. However, zero DC component can be obtained for any bandwidth by using a Gabor filter, which is Gaussian on a logarithmic scale; this is known as the Log-Gabor filter, as shown in Figure. 6.

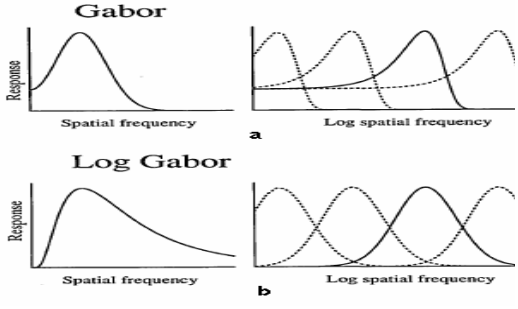


Figure 6. Comparison of the Gabor and Log-Gabor function [15].

Indeed, the phase of the multi-resolution analysis is more informative than its amplitudes, which are very sensitive to the illumination problems. In this way, the phase of filtred image was quantized using four-quadrants of J. Daugman [11], when going from one quadrant to an adjacent quadrant one bit is changed as shown in Figure. 7.

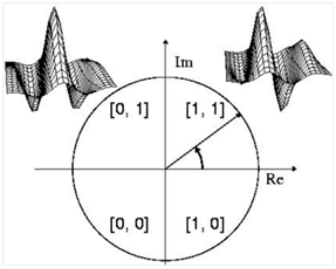
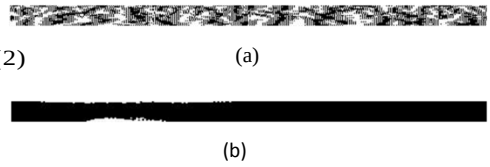


Figure 7. Quantization Phase [11].

The encoding process produces a bitwise template containing a number of bits of information (as shown in Figure. 8 (a)), and a corresponding noise mask which corresponds to corrupt areas within the iris pattern, and marks bits in the template as corrupt (as shown in Figure. 8 (b)). The total number of bits in the template (9600 bits) will be the angular resolution (240) times the radial resolution (10), times 2, times the number of filters used (2).



(a)

(b)

Figure 8. Iris encoding , (a) binary code, (b) mask code.

III. AUTHENTICATION MODE

A. Used database

The proposed method has been tested on Casia v1 database [16] in order to evaluate its performance in two operating modes: authentication and identification. Casia v1 database contains 756 iris images from 108 individuals. For each person, 7 images were acquired in two separate sessions in few weeks, 5 iris images were used for the learning and the rest for the tests.

B. Introduction

In authentication mode, it is necessary to ascertain whether a person is who they claim to be. It is therefore to compare the distance between two features vectors compared to a predetermined threshold during a learning phase [13].

C. Comparison and decision- Hamming Distance

The comparison of features vectors of two irises is performed by the Hamming distance as follows:

$$HD = \frac{\left\| (codeA \otimes codeb) \cap maskA \cap maskB \right\|}{\left\| maskA \cap maskB \right\|} \quad (3)$$

Where codeA and codeB are two codes calculated from two images of iris by the process previously described, and maskA and maskB represent their associated masks. Literally, the Hamming distance calculates the number of different and valid bits for the two irises between the codeA and the codeB. In fact, more the Hamming distance is smaller the two codes are similar. A distance of 0 corresponds to a perfect match between the two irises images as two iris images of different person have a Hamming distance close to 0.50.

D. Calculation of decision threshold

To determine the value of the decision threshold, we calculated for each threshold the different evaluation of the verification process i.e. False Acceptance Rate (FAR) and False Rejection Rate (FRR).

TABLE I. FALSE ACCEPTANCE RATE (FAR) AND FALSE REJECTION RATE (FRR) FOR DIFFERENT LEVELS.

Threshold	**FAR(%)**	**FRR(%)**
0.05	0	100
0.1	0	100
0.15	0	99.86
0.2	0	94.57
0.25	0	70.06
0.3	0	35.14
0.35	0.11	14.06
0.4	0.64	5.42
0.41	**1.39**	**4.45**
0.45	25.65	0.92
0.5	98.20	0
0.55	99.99	0
0.6	100	0
0.65	100	0
0.7	100	0

1) Discussion

We note from Table I. that the best rate of false acceptance and false rejection are FAR=1.39%, FRR=4.45% that correspond to a decision threshold equals to 0.41.

Figure. 9 represents the ROC curve (Receiver Operating Characteristic) which shows the False Acceptance Rate (FAR) according to the False Rejection Rate (FRR).

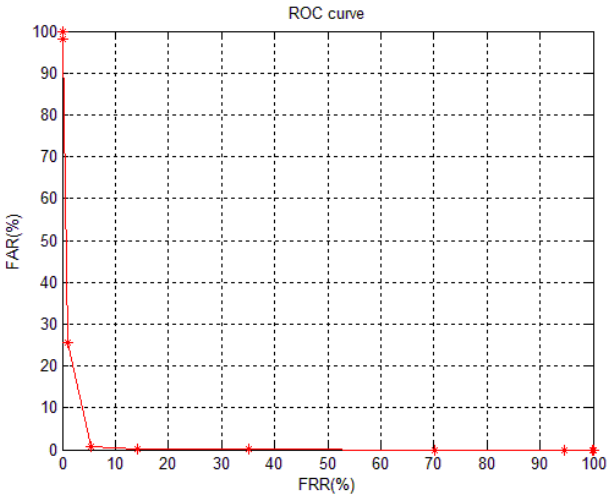


Figure 9. ROC curve (Receiver Operating Characteristic).

E. Evaluation criteria

There are many evaluation criteria of biometric verification system such as: HTER (Half Total Error Rate), TER (Total Error Rate), the most used is the EER (Equal Error Rate).

1) EER (Equal Error Rate):

The EER is the operating point for which the false rejection rate is equal to the false acceptance rate (as shown in Figure. 10).

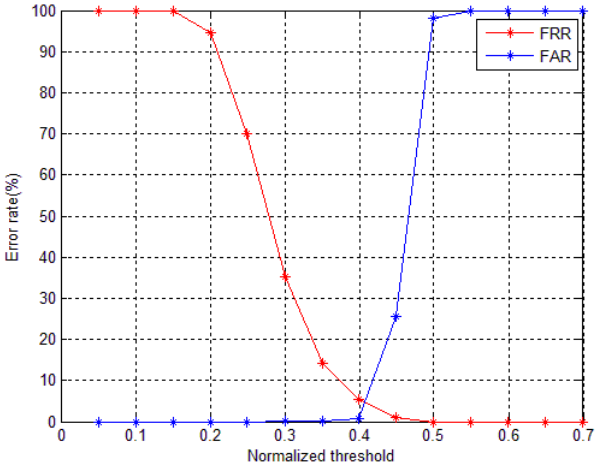


Figure 10. ROC curve (Receiver Operating Characteristic) which determine the EER.

2) Discussion

Figure. 10 represents the ROC curve that shows the FAR and FRR according to the normalized

threshold, the intersection point of FAR and FRR curves correspond to the value of EER which equal to 4.69%.

IV. IDENTIFICATION MODE

A. Introduction

In identification mode, it exists two types of biometric systems: a closed system to insure the existence of a candidate in the database, and an open system that cannot insure the existence the candidate in the database. In our work, we have considered the closed system [13].

B. Multiclass SVM based Approach.

The support vector machine (SVM) is a well accepted approach for pattern classification due to features and promising performance. Support vector classifiers devise a computationally efficient way of learning good separating hyper plane in a high dimension feature space. In this work, we apply multi class SVM to classify the iris pattern due to its outstanding generalization performance. Here, the SVM is employed as an iris pattern classifier because of its advantageous features over other classification scheme and also because of its promising performance as a multiclass classifier. In an SVM, a few important data point called support vectors (SV) are selected on which a decision boundary is exclusively dependent [17].

The SVM is also well suited for the case where the sample proportion between two classes is poorly balanced [18].

In this method, we used Libsvm 3.11 tool [19], that adopting approach one against one. We chose it after doing the following comparison [21] "1-against-the rest" is a good method whose performance is comparable to "1-against-1." We do the latter simply because its training time is shorter.

C. Results – discussion

TABLE II. RESULTS OF THE TESTS ON CASIA V1 BY BOTH METHODS.

Casia v1	Identification rate (%)	Classification rate	EER (%)	FAR (%)	FRR (%)
L.Masek method	96.30	208/216	5.4	1.61	5.90
Proposed method	98.61	213/216	4.69	1.39	4.45

1) Discussion

To be clear, we integrated our module of identification to the iris authentication system of Libor Masek, on purpose to make it as an iris recognition system. As shown in table II, our method is more accurate than L. Masek method, where the proposed method achieves the rates of 98.61%, 213/216, 4.69%, 1.39%, and 4.45%, for the identification, the classification, EER, FAR, FRR, respectively, on whole Casia v1 database (756 iris images). While the obtained results of L. Masek method on whole Casia v1 database (756 iris images) achieves the rates of 96.30%, 208/216, 5.4%, 1.61%, and 5.90% for the identification, the classification, EER, FAR and FRR, respectively.

Finally, we conclude that our system is slightly reliable as Masek system in terms of overall accuracy.

V. CONCLUSION

The objective of our work is to pre-process: segment, and normalize the iris, and characterize: Extract parameters and encode the iris. For the segmentation part, the detection of the iris/pupil circles was performed by Hough circular transform. We delimited the upper and lower parts of the eye by two segments by using the linear Hough transform, which gave us a good segmentation despite some errors due to the variation of the light intensity. Iris normalization part was performed by the Daugman rubber sheet model with resolution of 10x240. This stage was analyzed by the bench of two 1D Log- Gabor filters to generate a binary code of 1200 bytes. Hamming distance was used to establish the authentication process with a global FAR of 1.39%, and a global FRR of 4.45%. The classification of the obtained data was done by Multiclass SVM, which based on the approach one against one. This stage was applied to improve the identification process. The obtained results of the identification are very satisfactory of a rate equals to 98.61%.

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Comparative Study of Quality Measures of Sequential Rules for the Clustering of Web Data

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***Abstract*—To exploit large databases in the Web, data mining techniques have been applied. Among these techniques, the cluster analysis and the extraction of sequential patterns are considered to be the most important aspects in the process of exploring the web to find large groups.**
Web data that we handle are streams of sequential data where time plays a vital role in sequential patterns found to extract sequential rules. In this case, the ordering of events must be taken into account in the measure of calculation in order to measure the quality and interest of a rule.
The purpose of this study is to construct a model of clustering based on the grouping of sequential rules by quality measures. We aim at the end of our study to detect a good measure of applicable data quality and provide a good partitioning through the measures evaluation of the clustering quality.

Keywords—clustering, sequential patterns, sequential rules, quality measures, Web data, measurement devaluations clusters

VI. INTRODUCTION

The important growth of information available on the internet requires tools to search for more efficient and effective strategies to discern relevant information from hundreds or thousands of page views that can be structured by an analysis of web users.

To understand better the behavior of browsers and satisfy their needs, it is imperative to process and analyze these data by applying data mining techniques such as: association rules, classification, clustering and sequential patterns. The goal is to discover hidden relationships between users and useful as well as between users and Web objects and consequently improve the performance of web services.

Among these techniques, cluster analysis and sequential patterns can be considered as the most important aspects in the process of Web Mining which is a stream of sequential data when time is in the essence of the sequential rules extracted.

In the case of extracted rules from sequences, the scheduling events in the calculation of the measurement should be taken into account. The measures derived from conventional measures, support and confidence are most used to characterize the sequential rules. However, the excessive use of these two measures is not sufficient to ensure the quality of detected rules. As part of this study, there is a large number of measurements to characterize the association rules alongside the choice of a measure depend largely on the scope and criteria that the measure must satisfy. In the context of sequential rules, measures require a non-trivial adaptation to reflect the order of the events that make up the rule.

Our aim behind this study is to create a model for clustering web users based on sequential patterns and clustering rules through quality measures. At the end of our study, we expect to detect a good measure of quality that guarantees a good partitioning of our data in terms of assessing the quality of clustering and computation time measurements

VII. CLUSTERING TECHNIQUE [1] [2]

Clustering may be defined as a set of methods used for cutting a set of objects into groups (clusters) based on the attributes that describe. The goal of clustering is to understand how to group objects in the same cluster observations to be similar according to some metric (homogeneity intra-class) and place comments deemed dissimilar in separate clusters (inter-class heterogeneity). Good data classification must optimize a criterion based on the inertia in the goal to minimize the intra-class inertia or maximize inter-class inertia.

A good clustering method ensures high similarity intra-group and low similarity inter-group dependent grouping criteria used by the method. In the literature, the clustering is based on two main approaches: the hierarchical approach and the approach of partitioning

A. Hierarchical Method

These methods are gradually classed hierarchically, ie, a tree which is called a dendrogram. Algorithms based on this method are trying to create a hierarchy of clusters; the most similar objects are grouped in clusters at lower levels, while the least similar objects are grouped

in clusters at the highest levels. In fact, there are two subtypes: agglomeration and division

B. Partitioning Method

The partitioning data is used to divide a series of data in different homogeneous clusters. Its principle is to divide the set of individuals in a number of classes by using an iterative optimization strategy. Subsequently, the general principle is to generate an initial partition, and then try to improve it by reallocating data from one class to another. Unlike hierarchical algorithms that produce a class structure, the partitioning algorithms produce one partition which leads to seeking local maxima in optimizing an objective function which reflects the fact that individuals should be similar within the same class and dissimilar from one class to another.

VIII. SEQUENTIAL PATTERNS IN THE WEB [3]

- A transaction is for a user C, a set of items representing all visited page views by C on the same date. In a database, a transaction is written as a triplet: <id customer-id-date, itemset>. An itemset is a non-empty set of items noted (i1i2 ... ik), where ij is an item.
- A sequence is a non-empty ordered list of itemsets denoted <s1s2 ... sn> where sj is an itemset (a sequence is a series of transactions with an order relation between transactions). A data sequence is a sequence representative visits a browser.

  We consider streams of sequential data in the web, or T1; T2 ... Tn transactions ordered by date and is growing itemset (Ti) all items corresponding to Ti, then the data sequence is <itemset (T1) itemset (T2) ... itemset (Tn)>.

IX. STUDY OF ALGORITHMS SEQUENTIAL EXTRACTION: REASONS FOR THE GENERATION OF RULES SEQUENTIAL [4] [5]

In the literature, several algorithms have been proposed; we briefly introduce the pioneer GSP algorithm, the PSP algorithm, the algorithm Spade and PREFIX-SPAN algorithm

A. GSP Algorithm (Generalized Sequential Patterns)

This algorithm starts by sorting the initial database based on the unique identifier as the primary key and CID as a secondary key. The use of the identifier of this time base is to transform it into a sequence data base, and it is the latter which is analyzed by the algorithm. After making the first point of the sequence-based data to determine the set of frequent sequences, the GSP generates all k-candidate sequences of step k from the (k-1) frequent sequences step (k-1) by performing the join of F (k-1) with itself, called self-join of F (k-1).

The algorithm alters the phase between generation of the candidate sequences and calculation phase carriers generated sequences to determine the common points among them. It is based on the hash tree to represent the candidate sequences that will be stored in the leaves.

B. PSP Algorithm (Prefix tree for Sequential Patterns)

The PSP algorithm provides a data structure prefix tree to represent the candidate sequences or any path from the root to a node of the tree represents a single candidate. Moreover, any candidate sequence is represented by one and only one path of the root to a node. The candidates' generation of length 2 is similar to GSP, by cons for the higher levels, PSP pulls profile the structure of the prefix tree as follows: for each leaves of the tree, PSP Research the root item represented by x. Then, it stretches the sheet for building these copies of son of x. In this step, the algorithm applies a filter for only generating sequences that it knows in advance that they cannot be frequent.

C. SPADE algorithm

This algorithm performs a single reading of the sequence database to represent it in the main memory in a form of sequence of occurrences, for all subsequent treatments will be made on these lists. To generate the candidate sequences, SPADE offers to subdivide the space research equivalence class. The candidates generation of length (k + 1) is performed by temporal joins between two; all the lists are frequent occurrences k-sequences belonging to the same equivalence class k, ie those sharing the same prefix length of (k-1). The calculation of the support of candidates is to verify the cardinality of occurrences obtained lists and keep only the frequent sequences

D. PrefixSpan Algorithm (Prefix Projected Sequential Pattern mining)

This algorithm is proposed to reduce the number of generated sequences. By exploiting like previous algorithms common prefixes that often present data sequences. However, its strategy is much different to the extent that it does not generate any candidate sequence during different phases of the research. The algorithm performs successive projections of the base sequence data for the partition based on common prefixes. In its first phase, it identifies all frequent items (1-prefixes), and it builds intermediate bases which are projections of the latter on each frequent 1-préfix, which built the second and final round of base sequences. The algorithm seeks to grow the length of sequential patterns using this method recursively.

X. GENERATION OF SEQUENTIAL RULES AND MEASURES OF QUALITY RULES [6]

The generation of rules is much less expensive than the generation of frequent patterns since it is no longer necessary to the expensive route of the database. To generate the rules, we consider the set F of frequent patterns found in the previous phase. From these frequent subsets, we can generate all the valid rules in the context of data mining their respective Trusts exceed the minimum threshold of minimal support and confidence.

Be the rule in the form: x ⟶ y

A. Support: It is defined by

$$\text{Supp}(X \rightarrow Y) = p(X' \cap Y'). \quad (1)$$

It indicates the proportion of entities verifying both the premise and the conclusion of the rule. It is a symmetric measure and takes values between [0, 1]

B. Trust: It is defined by

$$\text{Conf}(X \rightarrow Y) = p(Y'|X') = \frac{p(X' \cap Y')}{p(X')}. \quad (2)$$

It says that the proposed entities give satisfying conclusion among those checking the premise of the rule. It is not sensitive to the size of data. Accordingly, It is a non-symmetric measure and takes values between [0, 1].

The number of valid association rules in the sense of a measure of quality is often very high which creates a new problem for the user to know the difficulty of assessing the value of extracted rules. It is in this context that the quality measures have been proposed in order to quantify and rank the association rules.

There is several quality measures proposed in the literature, the most used are probably the support and trust. However, these measures can generate a very large number of rules that are very difficult to manage and many of which have little interest what makes these two inadequate steps ensure the quality of the rules. To overcome these weaknesses, several measures have been proposed to check several criteria, namely:

C. Recall: It is defined by

$$Rappel(X \rightarrow Y) = p(X'|Y') = \frac{p(X' \cap Y')}{p(Y')}. \quad (3)$$

This measure assesses the proportion of entities satisfying the premise among those which satisfy the conclusion of the rule. It is insensitive to the size of the data. It is a non-symmetric measure in which case measure takes values between [0, 1]

D. Lift: It is defined by

$$Lift(X \rightarrow Y) = \frac{p(X' \cap Y')}{p(X')p(Y')}. \quad (4)$$

This represents the ratio of independence between the premise and the conclusion of the rule. It is a symmetric and sensitive measurement data size. It takes values between

[0, + ∞ [

E. Conviction: It is defined by

$$Conviction(X \rightarrow Y) = \frac{p(X')p(\overline{Y'})}{p(X' \cap \overline{Y'})}. \quad (5)$$

It indicates that the number of examples against the rule is less than that expected by the assumption of independence between the premise and conclusion. It is a non-symmetric measure and takes values between [0, + ∞ [

F. Pearl: It is defined by

$$Pearl(X \rightarrow Y) = p(X')|p(Y'|X') - p(Y')|. \quad (6)$$

This measure is used to evaluate the interest of a rule with respect to assumption of independence between the premise and conclusion. It is a symmetric measure and takes values between [0, 1]

G. Pietetsky-Shapiro: It is defined by

$$Piatetsky(X \rightarrow Y) = np(X')(p(Y'|X') - p(Y')). \quad (7)$$

It assesses the interest of a rule from its deviation from independence. It is symmetrical, and sensitive to the size of data. It takes values between [-n, n]

H. trust-centered: It is defined by

$$\text{Conf}_{\text{centrée}} = p(Y'|X') - p(Y'). \quad (8)$$

It allows taking into consideration the size of the conclusion and measures the influence of achieving the conclusion by contribution more than the premise. It is sensitive to non-symmetrical and the size of data. It takes values between [-1, 1]

I. Loevinger: It is defined by

$$Loevinger(X \rightarrow Y) = \frac{p(Y'|X') - p(Y')}{p(\overline{Y'})}. \quad (9)$$

It standardizes the measurement confidence centered by the number of entities that do not verify the conclusion. It is sensitive to non-symmetrical and the size of data. It takes values between] -∞, 0 [

J. Reduced contraction: It is defined by

$$Contramin(X \rightarrow Y) = \frac{p(X' \cap Y') - p(X' \cap \overline{Y'})}{p(Y')}. \quad (10)$$

It evaluates the difference between the numbers of examples against a ruler. It selects the rules with more examples than against examples. It takes values between

] -∞, + ∞ [

K. New: It is defined by

$$\text{Nouveauté}(X \rightarrow Y) = p(X' \cap Y') - p(X')p(Y').$$

(11)

It measures the deviation from independence between the premise and the conclusion of the rule. It is symmetrically dependent on the size and data. It takes values between [-1, 1]

L. Sebag: It is defined by

$$Sebag(X \rightarrow Y) = \frac{p(X' \cap Y')}{p(X' \cap \overline{Y'})}. \quad (12)$$

It evaluates the ratio between the number of examples and examples against the rule. If the value is greater than 1, the rule has more than an example against such. It is not symmetrical and takes values between [0, + ∞ [

M. Degree of involvement: It is defined by

$$Ind\text{-}Implication(X \rightarrow Y) = \sqrt{n}\frac{p(X' \cap Y') - p(X')p(Y')}{\sqrt{p(X')p(Y')}}$$

(13)

It estimates the number of cons example relative to the expected under the assumption of independence quantity. It is not symmetrical and varies depending on the data size. It takes values between [-√n, + ∞ [

XI. CLUSTERING WEB USERS [7] [8]

Clustering of users in the field of web browsing sessions grouping, the web developer can help to better understand the browsing behavior of users to provide their personalized services most suited to their needs as quickly as possible. Therefore, understanding how visitors use the Web site is one of the essential steps of website developers that will implement intelligent Web servers in real time to be able to dynamically adapt their designs to meet the needs of future users

This work explores the concept of Web Usage Mining from web session is represented as a sequence characterized by the IP address of the browser, the visited pages and the date of each page. We propose in this work a new algorithm for clustering data represented web users based on frequent sequential patterns

A. *The log file for web data*

With the popularity of the WWW, very large amounts of data such as address or user requested URLs are automatically collected by Web servers and stored in files access log.
A log file is used to collect data by servers that represent the database web sequential. Each entry in the log file represents a request made by a client machine to the server.

A log is a set of entries in the Access log file. An entry G belonging to Log, is a tuple:

$$g =< ip_g, \{(l_1^g.URL, l_1^g.time), ..., (l_m^g.URL, l_m^g.time)\}$$

(15)

Such that for 1 <= k <= m, lgk.URL represents object requested by the browser g to date lgk.time and for all

1 <= j <k, lgk.time> lgj.time

B. *Disadvantages of clustering approaches*

Under the data clustering, the methods mentioned above were the main limitation of being dependent on baseline (initial centers) representing clusters defined previously. They build partition k clusters of base D of n objects and gradually permit more refined classes and therefore can give the better classes. In fact, the algorithms need to run multiple times with different initial states to obtain a better outcome by following each iteration the reallocation mechanism that reallocate points between classes. Each initialization (set number of clusters) corresponds to a different solution (local optimum), which can in some cases be far from optimal. A naive solution to this problem is to run these algorithms multiple times with different initialization and retain the best combination found. The use of this solution is limited due to its high cost in terms of computation time and the number of steps for the best score can be obtained after repeated execution of the algorithm.

XII. CLUSTERING APPROACH PROPOSED WEB BASED DATA MINING SEQUENTIAL PATTERNS

To overcome the limitations of clustering methods, we rely on sequential patterns to establish our classification model uses data from the web. Among the extraction of sequential patterns algorithms presented above, we looked at Spade algorithm for the following reasons:

- It requires only one reading the database to represent the sequences as lists of occurrences in the main memory
- It is based on common prefixes of sequences, so the group sequential patterns by equivalence classes and thus breaks down the problem into sub problems to be addressed in memory which reduces the memory space
- Unlike the PSP and GSP are search algorithms by level algorithm, SPADE does not depend on I / O operations in the phase count of the support which triggers a reading of the entire database

Consequently, these features reduce the response time of the algorithm SPADE.

As part of the proposed quality measures, there is a large number of measurements to characterize the association rules and the choice of a measure

depends largely on the scope and criteria that the measure must satisfy. In the case of association rules derived from sequences, the scheduling events should be considered in the calculation of the measurement. Both measures, derived from traditional measures of association rules used to characterize the rules sequential measures are support and confidence. The algorithms using these measures generate a large number of rules that are very difficult to manage and many of which have little interest. Then, the condition of support that drives the extraction process removes the rules with little support while some may have a very high confidence and can have a real interest. Finally, the exclusive use of quality measures and Trust Support not enough to guarantee the quality of the rules detected.

To overcome these problems, the measures described above have been proposed. As part of our study based on web sequential data, we exclude the measure: novelty, Degree of involvement, Pietetsky-Shapiro as its measures depend on the size of the data while we process large web data where the size should not be intervened in the evolution of the function. In addition to this reason, the new measure does not satisfy the condition that the measure must tolerate little against examples to keep the interest of the rule. Once patterns are extracted, the set of rules is generated and will be evaluated to understand better the value of every extracted rule. Based on all of the quality measures we propose to consolidate the rules of associations with the same interest (quality) represented by a measured value.

The goal is to build a model of optimal classification adaptable to our database. For this purpose, we propose to make a comparative study of quality measures and generate only offer a further better quality of classification

After getting our clusters, data classification is based on the verification of the entire rule, knowing that any association rule is as**: if premise then conclusion.**

XIII. MEASURES OF QUALITY ASSESSMENT OF A CLUSTERING [9]

To assess the quality of clusters obtained after partitioning of the data, three steps are calculated

A. *Entropy:*

Is a measure of quality to measure how different classes of objects are divided into a cluster, such that:

- The entropy of a cluster C nr size is calculated using the following formula:

$$E(C) = -\frac{1}{logq}\sum_{i=1}^{q}\frac{n_r^i}{n_r}log\frac{n_r^i}{n_r} \quad (16)$$

Where q is the total number of clusters and n^i_r is the number of sequences of the ith cluster that are part of the cluster C.

- Entropy Clustering is then given by the formula:

$$Entropie = \sum_{r=1}^{k}\frac{n_r}{n}E(C_r) \quad (17)$$

Where n is the total number of sequences.

We consider a small entropy value which indicates a good clustering with respect to the reference clustering.

There are other steps to get a good score which is to minimize intra inertia and maximize inter inertia:

B. *Intra Inertia*

- The inertia of a intra-cluster measures the concentration of points cluster around the center of gravity is calculated by:

$$jk = \sum_{i\in ck} d^2(xi, uk) \quad (18)$$

u: is the center of gravity

$$uk = \frac{1}{Nk}\sum_{i\in ck} xi \quad (19)$$

Total Inertia intra partitioning is the summation of inertia within clusters. More inertia is low, the smaller the dispersion of the points around the center of gravity

C. *Inter Inertia*

- Inertia -inter a cluster measures the distance from the centers of the clusters together. It is calculated by:

$$jb = \sum_{k} N_k d^2(uk, u) \quad (20)$$

u is the center of gravity:

$$uk = \frac{1}{Nk}\sum_{i\in ck} xi \quad (21)$$

The total inertia inter partitioning is the summation of inertia inter clusters. More inertia, the larger clusters are well separated in order to get a good score

XIV. IMPLEMENTATION

Our goal is to propose an approach based on frequent patterns approach to exploit various information relatives on the use of a website. The goal is to classify browsers of this site recorded in the log file in minimal time.

We implemented this algorithm on a platform java log file test 1000 records over a period of 4 days. We first perform preprocessing of the log file that was done in two phases:

A. *Phase 1*

- Removal of unnecessary queries since their appearance does not reflect any behavior relating to the Internet that is invalid queries, requests for images and multimedia files type

Mea-sures	Nb cl	Nb reg	M_V	intra	Ent-ropy	Tp
trust centered	11	6	-26, -23 -22, -20 -17, -16	448.55	9.34	5266
Pearl	8	6	320,67, 106,94 100,52, 181,124	418	10.4	4875
Convictio n	6	6	0,1,2, 3,4,6	435.61	9.73	5110
Reduced contractio n	**2**	**6**	**-1, -2**	**287.76**	**2.88**	**4600**
Loevinger	**2**	**6**	**-1, 0**	**287.76**	**2.88**	**4562**

the extension (jpg,. wma ...), the scripts usually downloading and requested by a user and leave the final urls that reflect the Web pages assigns the extensions page: html, htm, php, ...

- Delete records with a "post" method

B. Phase 2

We applied the Spade algorithm in order to extract frequent patterns then extract sequential rules. We subsequently consolidated these rules and classified our browsers in clusters so defined.

Mea-sures	Nb cl	Nb reg	M_V	Nb iter	intra	Ent-ropy	Tp
Pearl	4	4	320, 117, 181, 104	6	565.62	11.3	5234
trust-centered	3	4	-26, -23, -22	2	285.72	4.34	4984
Convicti on	3	4	2, 4, 6	2	284.22	4.34	5219
Loeving er	**2**	**4**	**-1, 0**	**2**	**280.48**	**2.78**	**4800**

TABLE I. Results of this study for supp=2

TABLE II. Results of this study for supp=3

For a comparative study of quality measures on the same data set, we combined our rules according to several quality measures for each measure and describe all clusters found subsequently to classify all our browsers.

The algorithm stops when the number of iterations is reached or achieves stability.

At the end of our study, we must maximized the inertia inter or minimized the inertia intra. We calculated each defined measure:

- Nb_cl: represents the number of clusters generated for each calculated measure
- Nb_reg: represents the number of sequential rules for all generated cluster
- M_V: represents the measurement value obtained by combining rules
- Intra: represents the total inertia of all partitions
- Entropy: represents the total entropy of all partitions.
- Tp: Represents the calculated execution time Mili-Second
- nb_iter: represents the number of reached iterations.

- **To min support = 2**

After several values of iterations, we set, the maximum number of iterations to 5 and we fix the minimum support = 2 and minimal confidence 0.33

We launched the algorithm on measures and Recall Lift and Sebag. We found that it generates only a single metric value and therefore only one cluster in which case they were excluded for this data.

- **To min support = 3**

We launched the algorithm on measures Reduced contraction

Lift, Sebag, Recall . We found that it generates only a

single metric value and therefore only one cluster in

which case they were excluded for this data.

XV. DISCUSSION

The best classification for a sup = 2, is the one that minimizes the intra and provides a small entropy value, for these reasons, we choose for our sample data, Reduced contraction and Loevinger measures because they ensure the best clustering in minimum execution time

The best classification for a sup = 3, we choose the measure Loevinger as it ensures the best clustering in minimum execution time

After comparing the results of the two tables, Loeviner measure is selected for support = 2 and confidence = 0.33 because:

• It generates for the same number of cluster = 2, a smaller
number of rules than that obtained by support= 3
• It executes in a smaller number of iterations than that
obtained by support = 3
• It provides a value of entropy and intra better than that
obtained by support = 3
• It runs in a smaller execution time

XVI. CONCLUSION

We presented in this paper a comparative study of quality measures for grouping of associations rules.

Our job is to build a model of clustering based on sequential patterns and clustering of sequential extracted rules in order to categorize Web data.

To this end, we conducted a comparative study of measures of quality of association rules to detect good quality measure applicable to our data and provide a good partitioning through the evaluation measures of the quality clustering in a minimum execution time.

We found at the end of our study for the same parameters input and the same sample data, the measure Loevinger meets the criteria initially namely the evaluations measures of the quality of obtained clusters

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Exploitation of ontology by the Jena semantic API

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Abstract—Ontology's are currently among the most talked in knowledge engineering models to define structured vocabularies, gathering useful concepts in a domain and their relationships used to organize, share information unambiguously. Once created, the ontology can serve or be used directly by the user, it is necessary to represent using a formalism that will acquire its importance once integrated.

This paper presents the exploitation of ontology by the Jena semantic(Application Programming Interface) for a classification of relations in enterprise. Our approach is to read an ontology previously created via the Jena API using the Eclipse environment, in order to extract the desired information. The approach is applied to a local enterprise and the result is given in the form of relations. These relationships will be classified according to their kind in order to improve the performance of the concerned enterprise.

Index Terms— Ontology, Jena API, relationships, classification.

I. INTRODUCTION

To address problems the heterogeneity due to the development and disparity data, approaches have emerged and are thriving as ontology's. Ontologies are intended to improve the use of information resources by positioning themselves as a representation model consisting of concepts linked by relations structured hierarchically. They allow for example to organize knowledge according to the area in question, to detect inconsistencies as well as to improve or optimize relationships. After their creation, the user can take full advantage of ontologies only if they are exploited through the use of tools.

This paper presents the exploitation of ontology by the Jena Semantic API for classification of relations in enterprise. In the second section, we first briefly give the notion of ontology. We chain by presenting tools, focusing on the Jena API to exploit ontology; then we present our approach. In the next section, the application of the process on the local enterprise of transformation wiredrawing steel is proposed. The result will list all information contained in the ontology (classes, relationships, etc.) or to filter them according to specific needs. Then, we assign on each extracted relationship nature and weight to classify in order to improve business performance.

II. PROPOSED APPROACH FOR THE EXPLOITATION OF ONTOLOGY

A. Exploitation of ontology

1) The concept of ontology: According to Gruber [1], an ontology is a formal, explicit specification of a conceptualization. In general, ontology's describe the structure and semantics of data. They enable users to organize information to concepts, attributes and relationships [2], according to a domain ontology allows a meta-knowledge representation. Ontology's therefore provide a common vocabulary defining the meaning of terms and relations between them.

2) Tools for the ontology exploitation: There are few tools dedicated to ontology exploitation, the most used are the Jena [3] API and Jade platform [4].

Jena is an API (Application Programming Interface) for Java applications of the Semantic Web. This API can read and manipulate ontologies described in the RDFS model (Schema Resource Description Framework) or in the Ontology Web Language (OWL). It can use also to apply some inference mechanisms.

Jade (Java Agent Development Framework) is a multi-platform agents. The exploitation of ontology using Jade results in a process suitable for mapping Jade agents. This process is tedious and it requires a domain expert.

B. The proposed approach

1) Ontology building: The preliminary step is the construction of ontology. For building an ontology, we have adopted the Protege environment. Protege [5] is a free Java tool ; it is

produced and made available by the laboratory Stanford Medical Informatic. It plays a crucial role in assisting the developer of the ontology when building the ontology through a graphical modular environment. We have worked with versions 3.4 and 4.1 Beta.

2) Ontology reading: Knowing that the Jena API is a framework designed to exploit ontology's, we adopted this tool to read the ontology in order to extract all relationships.

This API includes a set of programming tools [6] using the
Java programming language. Jena has object classes to represent graphs ; these classes are named:

- *Resource (Subject):* A resource is an entity that we to refer. It can even be a web page, a link, a particular user identity.
- *Properties (Predicate):* A properties specified the characteristics of the resource.
- *Object (literal):* A literal value represent data or resource.

3) Classification of relationships : We assign to each extracted relationship a nature of type and a weight to be able to class these relations for improved performance. In the context to enhance the performance of the enterprise, we associate the concept of nature with respect to the notion of efficiency and effectiveness [7] [8].

The Efficiency relates to the following questions: What material, human and financial resources have been mobilized effectively? The effects achieved are they in line with all the resources used? Could we have achieved the same results at a lower cost?

The Effectiveness measures whether the expected achievements were implemented.

Depending on the nature of the relationship (efficiency / effectiveness), we assign a weight for each considered relation. The final result will allow to classify the relationships in order to improve the performance of the concerned enterprise.

The Figure.1 illustrates our approach.

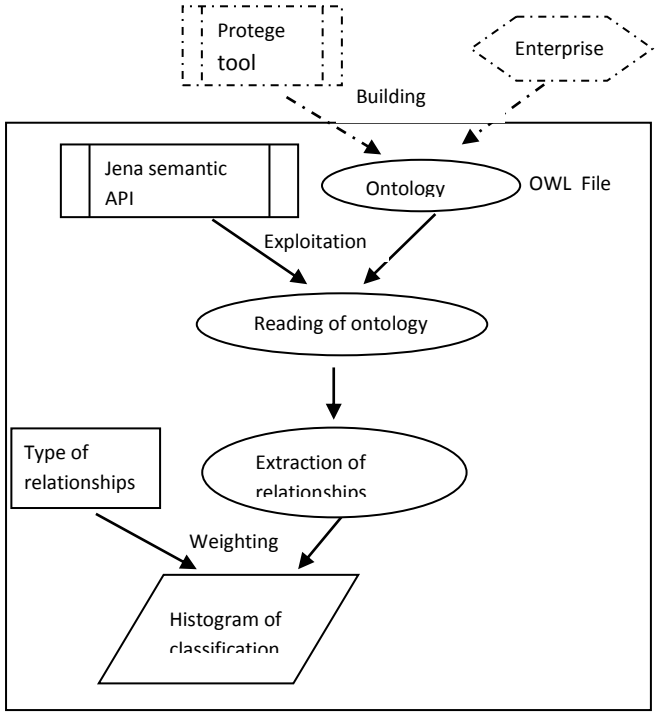

Figure.1. Proposed approach

III. APPLICATION TO ALGERIAN ENTERPRISE PRODUCTION

A. Specification of the enterprise

We apply the approach on a local manufacturing enterprise, involved in the transformation wiredrawing steel. The field of activity of the subsidiary is the production and sale of welded mesh panels, in rolls, concrete reinforcement and lattice girders [9].

The structural hierarchy of the enterprise consists of six departments *(commercial, , supply, maintenance, accounting, means and technical staff)* and two services *(quality control and industrial safety).*

The enterprise interacts with the outside world by nine entities: *customer, supplier, bank, EPO (port company), newspaper, court, wilaya, contributions* and *reservations.*

B. The adopted ontology

The first step in our approach is the ontology building. We consider the ontology for the interactions of the enterprise with the outside

world. This previously created ontology contains 29 classes including 9 relations with the outside world.

The nine relationships are:

- *R_secu* between Industrial safety service and wilaya.
- *R_appro* between Service of management stock and supplier.
- *R_achat* between the Sales service and EPO/ newspaper / bank / supplier.
- *R_compta* between Accounting service and customer / supplier/ bank.
- *R_manage* between Chief of management quality and customer/ supplier.
- *Appel_J* between Legal businesses and customer / supplier / court.
- *Ramene* between Sales force and the customer.
- *Reserve* between the Service of general means and reservations.
- *Cotise* between the Chief of social relation and contributions

After creation, we generate an OWL file and the figure 2 shows the hierarchy of classes and all interactions via the plugin OntoViz [10].

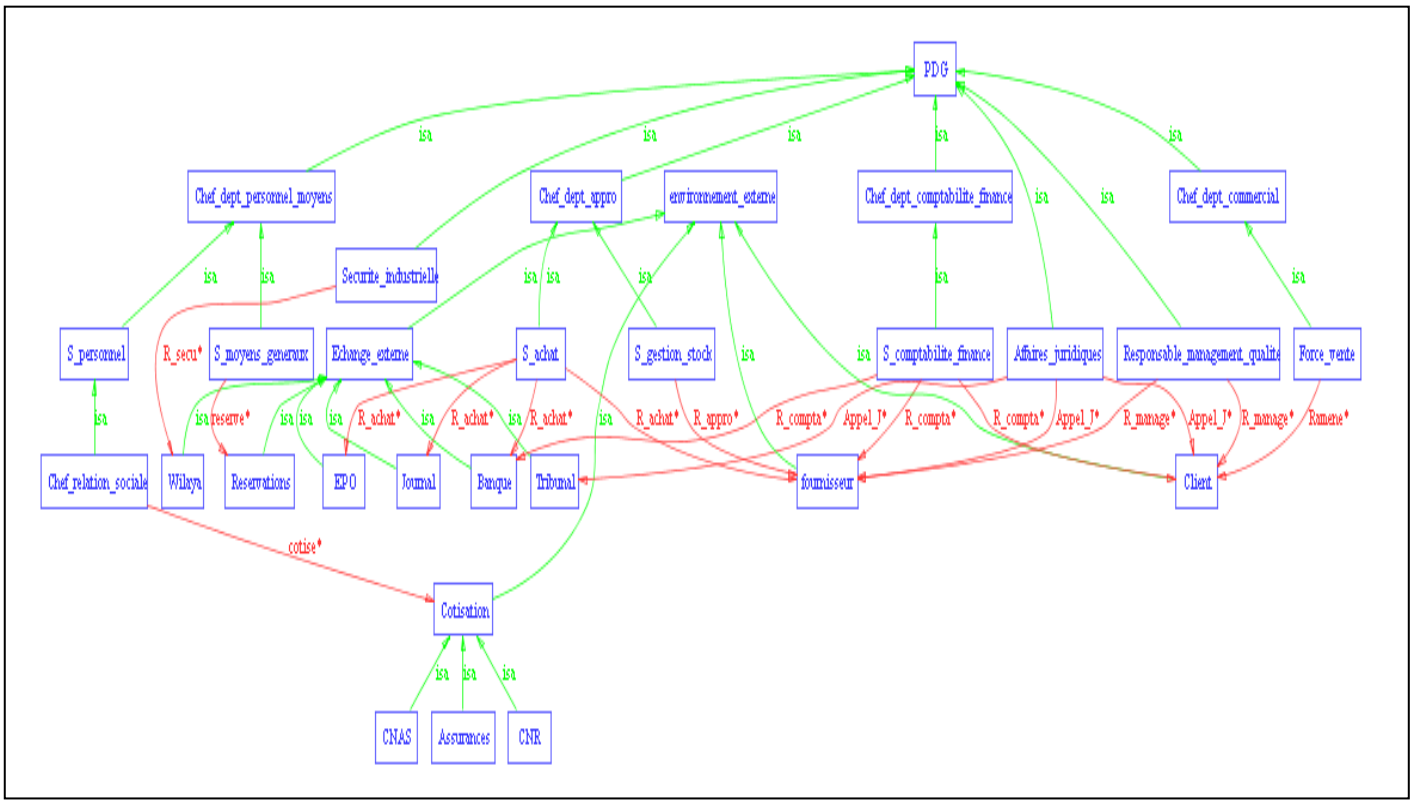

Figure.2. Interactions of the enterprise with the outside world

With:

The red color shows the hierarchy of classes *(isa).*
The blue color shows the class name.
The green color shows the existing relationships between the enterprise and the outside world.

C. Application of the approach

After integration of the Jena API in Eclipse programming environment, we read the OWL file in order to extract relationships.

ability to generate all existing owl file or set filters based on the three criteria outlined above: *subject / property / object.*

We obtain a resulting set of Relations *R:*
$R = \{R_1, R_2, ..., R_n\}$, where each R_i is related as a record with three arguments as the three criteria: *(S, P, O)* with
- *S:* Subject referring to a class or a relationship.
- *P:* Property referring the type of subject.

This criterion can take three choices as $P = P\ [t, d, r]$ with

- *t: type* (relationship or class)
- *d: domain* (input entity of the relationship)
- *r*: *range* (output entity of the relationship).
- *O:* An object that is a class.

To view the principle of our approach for extracting relationships, we make two experiments.

1) First experiment: For a first practice, no filter (criteria) has been introduced, so we get all the classes and existing relationships in our ontology. This result highlights all the classes and relations of the ontology. (Figure.3).

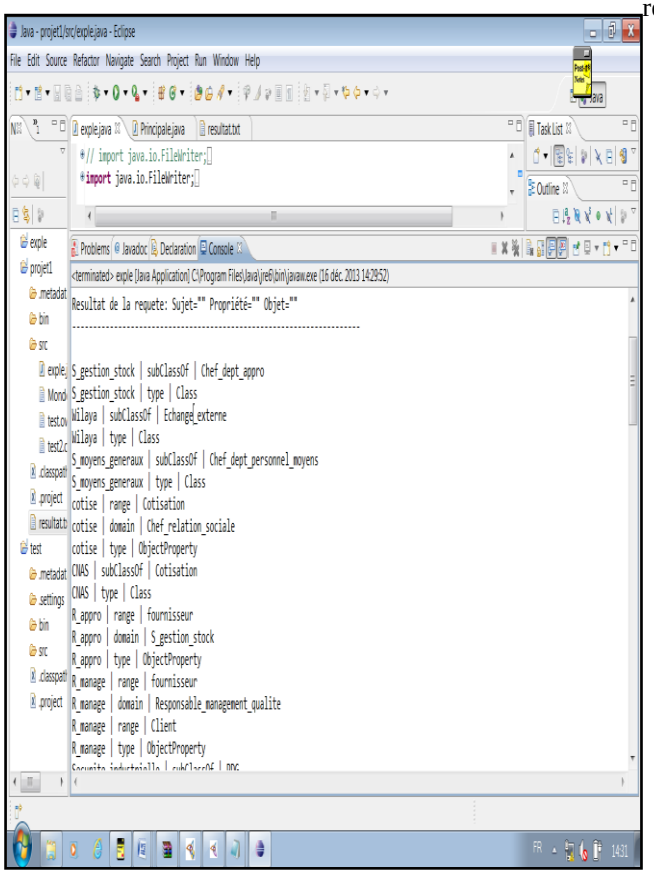

Figure.3. Reading and extract all informations of the ontology

For example, all the information of the relationship *R_appro* are displayed following the records:

R_appro | range | supplier
R_appro | domain | management stock service
R_appro | Type | objetProperty

For clarity, we provide the ability to filter this result.

*2) Second experiment :*Based on the three criteria Jena *(S, P, O)*, several combinations can be made according to one, two or three filters.

Our aim is to extract all relationships, so we choose as a filter criterion *P* (property). In this filter, there are three proposals on the choice of *P*: *t* (type), *d* (domain) or *r* (range). By choosing the domain, we have as output correspondence relations and classes of the form:

Relationship / domain / name of the class.

For example, the figure 4 lists for each relationship the input classes (domains).

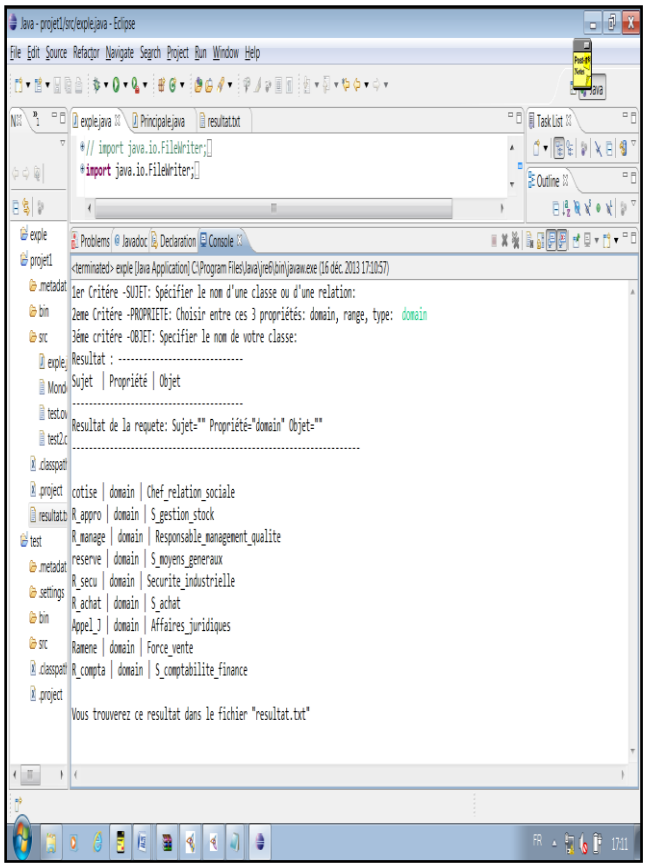

Figure.4. Generation of entities entered for relationships

So the relationship *R_appro* is refined to give:
R_appro | domain | management stock service

This result illustrates the generation of input entities for each relationship of the ontology. Following the same process, we can generate output entities by replacing domain by range.

These experiments allowed us to exploit an ontology and extract information according to our needs.

D. Classification of relationships

In order to improve the enterprise performances, we classify the extracted relationships along a nature that is efficiency and effectiveness, through a respective weight of 1 and 2.

Since the considered enterprise is a manufacturing company, we assign the highest weight (weight = 2) for effectiveness. The final weighted relationship is obtained par the product of the weight by the number of relations. Thus, these relationships are ranked in a graph following an histogram form (Figure. 5).

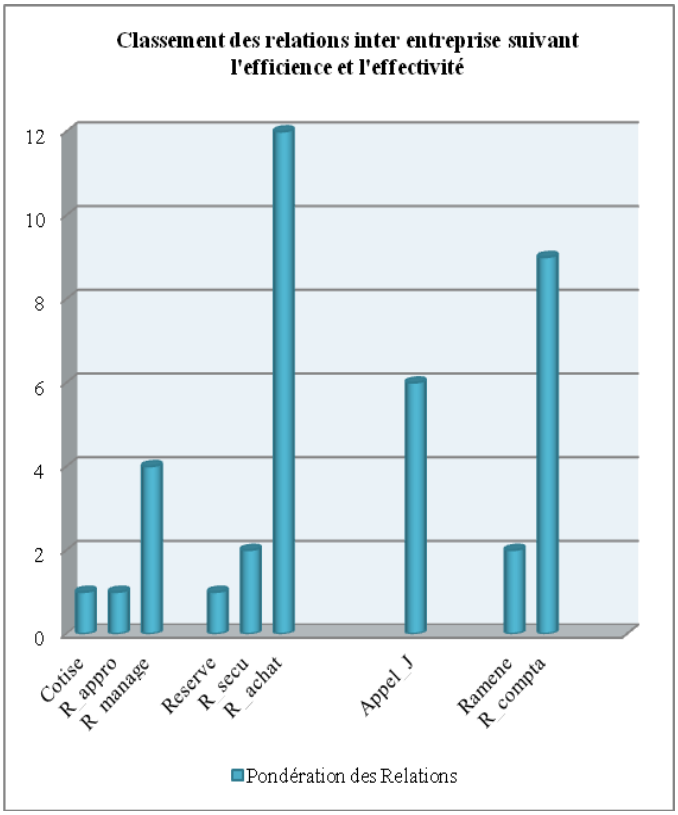

Figure.5. Classification of relationships

on that the external relationship *purchasing* (R_Achat) is the most important and must be treated in priority.

Indeed in the manufacturing context, the relationships with the outside world are fundamental to ensure efficient production. For example, The accounting relationship is paramount to finalize the purchasing and also the relationship of legal businesses (Appel_J) for solving conflicts.

IV. CONCLUSION

We have presented in this article the exploitation of ontology by the Jena API for a classification of relations. We discussed the notion of ontology and the Jena API while detailing the proposed approach.

Our aim was to exploit ontologies already created to extract various information for later exploitation. After studying the few existing tools, our choice is leaning with the Jena API since this framework provides a number of Java classes dedicated to handling ontologies which are described in the Ontology Web Language.

The case study was done on a real example of an enterprise of transformation wiredrawing steel. Following this study, we consider the ontology for the interactions of the enterprise with the outside world. So, we can read this previously created ontology and after that, we generated the information according to our needs like interactions. Extracted relations were classified according to their relative weight compared to the concept of efficiency and effectiveness in the context of production. The obtained rank allows giving priority relationships in this enterprise.

These preliminary results will be the subject of further studies to improve the enterprise performance.

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Toward an incremental development for real time and embedded systems

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Abstract-This paper presents a new methodology to development complex embedded systems for hard real-time applications, based on incremental model in order to make the latter compatible with the particularities of embedded systems. In this paper, we first introduce the methodology proposed and describe it step by step, based on SART((Structured Analysis Real-Time) and MARTE (Modeling and Analysis of Real Time and Embedded Systems) profile for analysis and modeling of real-time systems.

The suggested methodology is illustrate with a two case studies for development of hydrostatic bearing lubrication system and triaxial appartus system.

Keywords—Incremental model, Triaxial appartus system, Hydrostatic bearing lubrication system , RTES.

I. INTRODUCTION

REEL Time and Embedded Systems (RTES) are now omnipresent, and it is difficult to find a domain where these miniaturized systems have not made their mark, such as: (a) consumer electronics (b) home appliances (c) office automation (d) business equipment (e) automobiles **[1].**

Furthermore, the development of these hybrid systems consisting of mechanical, electrical and software parts, that run in a physical world is a very complex challenge, comes from the fact that RTES must interact with the environment and their particularities.

Among life-cycle process used in the development of RTES are V-model **[17],** SW/HW **[16]** and W-Model **[9].**The
commonly used for the development of embedded systems is the V-model for example in **[21].**

The V-model is denoted as a linear life-cycle process that follows a top down approach shown at the left side of the V, while validation and verification takes place using a bottom up approach shown at the right side of the V **[14].**

The main idea to remember is that when any changes to the application at any level whether, it is necessary once again falling all stages of development.

To overcome this problem, we propose the principle of Incremental model takes into account the fact that software can be built step by step.

The objective with this model is to identify parts, which can be developed from specification to executable code. The development of an increment may follow either a waterfall model or a spiral approach. Incremental development means dividing the requirements into suitable parts during the specification allowing for independent development of the different increments. The design and coding of one increment are followed by testing of that increment, which makes it possible for the developers to start implementing the next increment while the testers validate, verify or certify the first developed increment. Here, it is assumed that development and testing are performed by different teams.

The incremental approach hence allows for a good deal of parallelism between development and testing. The benefit from this parallelism is not only the possibility to work in parallel, but also that the testers really start testing the software to be delivered at an early stage. This is what solves the previous problem figure in V-model.

The contributions of this paper relate to presenting a complete methodology for the development of RTES based of incremental model **[3][5] [13]** and improve this model to
fit the distinct RTES. The main benefits of this methodology
are:

- Each development is less complex;
- It is possible to deliver and enable each increment;
- It allows a better smoothing of time and development effort through the parallelization of different phases.

The rest of this paper is organized as follows: section II illustrates our contribution, followed by an introduction of methods used (SA-RT and MARTE) in Section III. While section IV presents our case study, with a Experimenting methodology on a case study. Afterwards, section V presents our discussion followed by a conclusion in section VI.

II. OUR CONTRIBUTION

In this section, we provide a brief overview of the methodology proposed, as illustrated in Fig.2, which aims to develop novel model life cycle, based on incremental model depicted in Fig.1, to

improve existing practices in development of complexes real-time and embedded systems.
The methodology consists of three essential elements: assets
activities (incremental model), New activities , and tools (with the methods and techniques used in each activity).

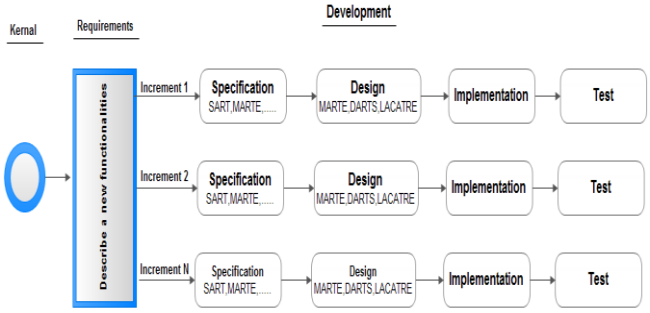


Fig 1**:** incremental model

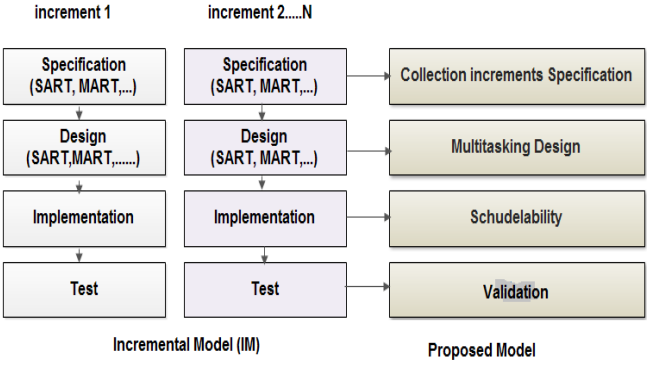


Fig. 2. An overview of our methodology

Initially, the left-level system design model are carried out using the Incremental model. When the developers execute the second increment the the right-level system design model
is starting, the third increment execute with IM model, then the proposed model therefore is carried out, until N increment the IM and proposed model are affected with consecutive manner.

Algorithm 1 Algorithm for our methodology

```
Begin
I=1; applied Incremental Model
For i=2 to N do
Begin
applied Incremental Model;
applied the proposed model ;(the novels activities)
I=I+1;
End
End
```

The main activities of this our methodology are:

The classical stages for incremental model: Specification,
Design, Implementation, and Test. with the activities proposed :
1. Collection increments Specification
2. Multitasking Design
3. Schedulability
4. Validation

Each of these stages must be followed by a phase designated her as shown in the figure, to confirm spell as follows: Collection increments specification followed by specification stage,
Multitasking design with Design stage and Schedulability followed by implementation, finally validation suited by Test stage.
Collection increments specification stage consists to add specification of increment i-1 (precedent increment) in specification of current increment to make a connection between the different increments. This stage allows the developers to see the common things between increments, like functions and avoiding non-recurrence, furthermore resources and try to reduce.
Multitasking Design stage offers to developers describe theirs multitasking application, and to express the architecture of system (the tasks, relation between tasks, access of critic resource).
Schedulability **[15]** stage is a primordial stage during all
development of RTES, it allows to verify the respect of times constraints.
Final validation will always be required in the completed system. This validation allows to valid all functionalities of system (all increments), when test valid each increment alone.
The aim of the Methodology-proposed is to provide a methodology that allows leveraging the productivity gains offered by incremental model. While the latter can contribute significantly to parrallized the different stages and minimize the faults of system from the minimization the need for re-validation activities.
The methodology enables developers to easily developed system for their own necessities with less complexity and allows the validation before next increment and total validation for all system.

III. PRESENTATION OF SA-RT AND MARTE METHODS

A. Presentation of the SA-RT method

SA-RT is **[9][22]** a short name for Structured Analysis Methods with extensions for Real Time.

The model is represented as a hierarchical set of diagrams that includes data and control transformations (processes). Control transformations are specified using State Transition diagrams, and events are represented using Control Flows.

Thus, SA-RT is a complex method for system analysis and design. This is one of the most frequently used design method in technical and real-time oriented applications adopted by various Case-Tools. It is a graphical, hierarchical and implementation independent method for top-down development (Fig.3).

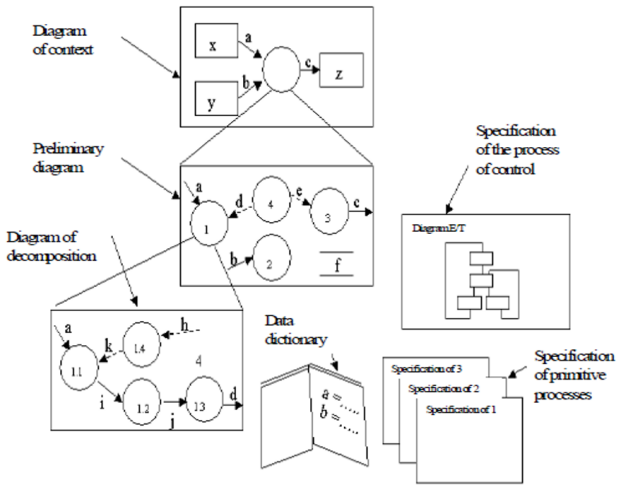


Fig. 3. Organization of an SA-RT model

The symbols of the Diagram of Context (Fig.4):

- The terminator is the element in end, final element that encloses the action.
- The flot of data is the final element that opens up on a last action.
- The flot of control is generally a tie back of the process toward the terminator. It can be a main element of the process.
- The termination is generally a direct tie between a terminator and the process **[23].**

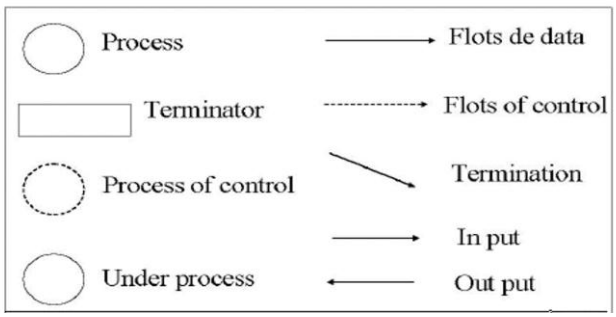


Fig. 4. Symbols of SA-RT method

B. Presentation of the MARTE profile

MARTE (Modeling and Analysis of Real-Time and

Embedded Systems) **[2][24][25]** is the UML extension profile dedicated to the modeling of Real-time and Embedded Systems (RTES). Standardized by the OMG.

MARTE profile consists of three packages named "MARTE

Foundation", "MARTE Design Model" and "MARTE Analysis Model", shown in fig.5.

"MARTE Foundation" package defines all basic foundational concepts required for design and analysis of real-time and embedded system. It provides model developers with constructs for modelling of non-functional properties (NFPs), time modelling, generic resource modelling (GRM), generic component model (GCM) and allocation modelling.

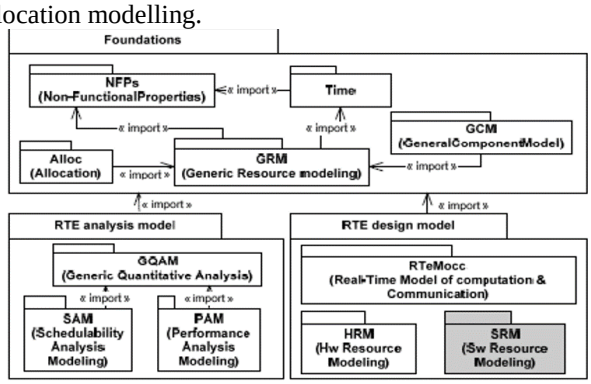


Fig. 5. overview of MARTE profile

"MARTE Design Model" package addresses model-based design, starting from requirement capture to specification, design and implementation. It provides high-level concepts for modelling both, quantitative and qualitative features of real-time systems/protocols. Further, it also provides means for detailed description of software and hardware resources used for execution of an application.

The package "MARTE Analysis Model" offers specific abstractions and relevant annotations that could be read by analysis tools. MARTE analysis is intended to provide trustworthy and accurate evaluations using formal quantitative analysis based on sound mathematical models. This package is sub-divided into three other packages, namely "Generic Quantitative Analysis Modeling" (GQAM), "Schedulability Analysis Modeling" (SAM) and "Performance Analysis Modeling" (PAM).

IV. CASE STUDY

To better illustrate the use of our methodology discussed in

Section II, a case studies are presented.

A. Case study 1: Hydrostatic bearing lubrication system

Rotating machinery is commonly used in many mechanical systems, including electrical motors, machine tools, compressors, turbo machinery and aircraft gas turbine engines. Typically exogenous or endogenous vibrations produced by unbalance, misalignment, resonances, material imperfections and cracks **[6]** affect these systems**.**

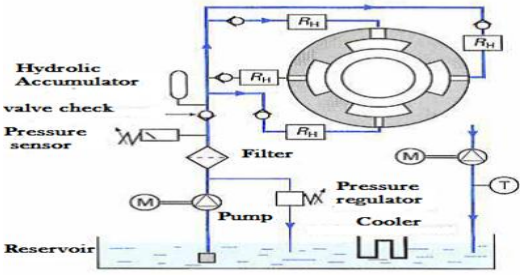


Fig. 6. Functionnement of hydrostatic journal bearing with four hydrostatic
Bearing.

To damp the vibrations has been proposed several methods: passive , active **[4][12]** and semi-active method **[11]** . Where passive methods are not enough to dampen the vibrations generated, a new smart hydrostatic journal bearing with four hydrostatic bearing flat pads fed by electrorheological fluid, has been designed to control rotor vibrations caused by imbalance and to reduce transmitted forces to the bearing **[8].**

So bearings are machine elements used to guide the rotating shafts **[7]**. The hydrostatic bearings can be used irrespective of the load and speed. They are used successfully in a large number of machines operating at low speeds and carrying heavy loads. Lubrication of hydrostatic bearings is an important process, but also complex. Because it consists of electronic and mechanical components that operate in a physical world.

This is what makes the development process is also difficult.

Functionnement :

Fig. 6 illustrate a functionnement of system. A pump supplies a bearing about 30 % higher than that required flow rate. The excess fluid returns to the reservoir via a pressure regulator. A pressure sensor is used to stop the rotor drive if the pressure reaches a value too low. Non-return valve and the hydraulic accumulator provide food bearing to a stop of the shaft. We can also provide a backup pump.

The flow is then derived to each cell on each portion of the circuit. Provision may be a check valve in case of overpressure in a cell. Resistance hydraulic HR should be placed as near the cell to avoid instabilities due to the pneumatic type lubricant compressibility. A pump may be necessary to ensure the return of the lubricant to the reservoir. A thermocouplee to control the temperature of the liquid at the outlet of the bearing and trigger stop if it becomes too large. Finally, a cooling system ensures a constant temperature on the power supply **[7].**

1) Experimenting methodology on a case study1: Here, we illustrate the various concepts present in our methodology by means of an effective real life RTES case study: hydrostatic bearing lubrication system.

After modeling of hydrostatic journal bearing lubrication system using the SA-RT method, we establish three diagrams as follows:

- Context diagram;
- Data flow diagram;
- Control flow diagram;

For this system, we carried out an increment(increment 1) to
verify the level of fluid tank. To achieve this increment, we
need to a sensor sends a signal when the low level (eg level
b), the sensor is considered a terminal send a data level low
= true or level low =false, finally needs an actuator here is that the pump will start.

- Specification /Design step

Figure 7 presents the context diagram of the SA-RT model of the system. In fact, the context diagram is constituted of one functional process « Control the level of liquid 0 » and 2 terminators (sensor and pump).

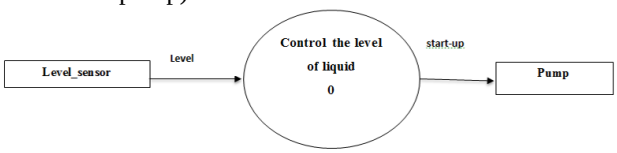


Fig. 7. Context diagaram

The Data flow diagram (Fig. 8) of the SA-RT model constitutes the first decomposition of the process presented in the context diagram. Then, we can break down the initial functional process of the application of control in three process: Acquirement process; Test process; command pump Process.

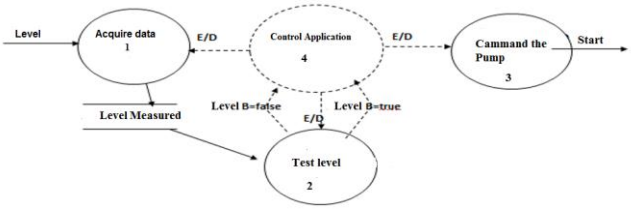


Fig. 8. Preminiraly diagaram

Now we pass in the second increment for control the pressure with the initial process « control the pressure » and 2 terminators
(the pressure sonsor and the regulator of pressure).Fig.9 present the context diagram of this and increment followed by the preliminary diagram (Fig.10).

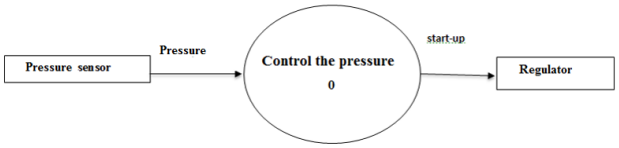


Fig. 9. Context diagram (Increment 2)

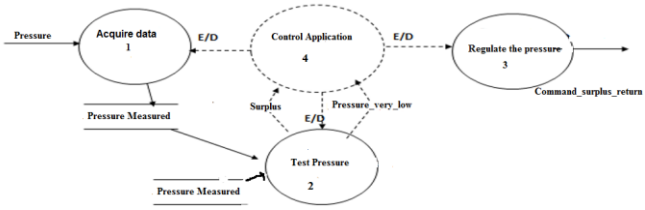


Fig. 10. Preliminary diagram (Increment 2)

- **Collection increments specification step**

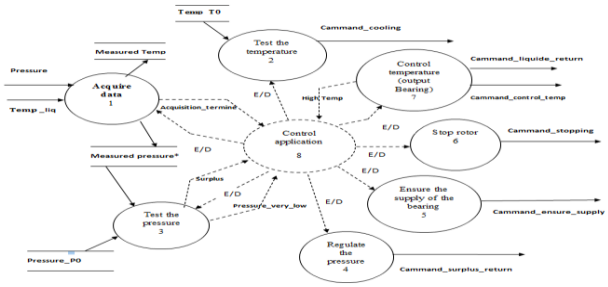
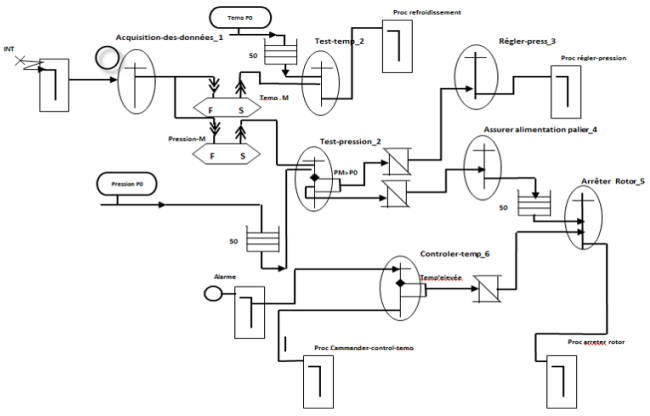


Fig. 11. Collection increment specification (context diagram).

After the implementation of several increments (acquisition data, test temperature, test pressure,...),the collection increments specification step is presented in Fig.11.



- **Multitasking Design step**

Fig. 12. Multitasking Design

Here the Multitaskig design step. Fig.12 illustrated the tracing of creation part of the application.

- **Development Systems /Environment**

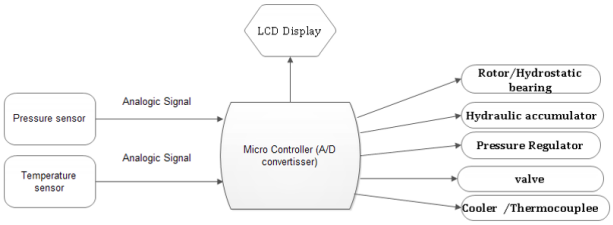


Fig. 13. Description of Hardware application

Fig.13 presents a description of the application.

This figure shows three parts: the inputs, and the microcontroller **[20]**. the outputs. The main role of the microcontroller is conversion A/D of the different inputs signals, and high level commands.

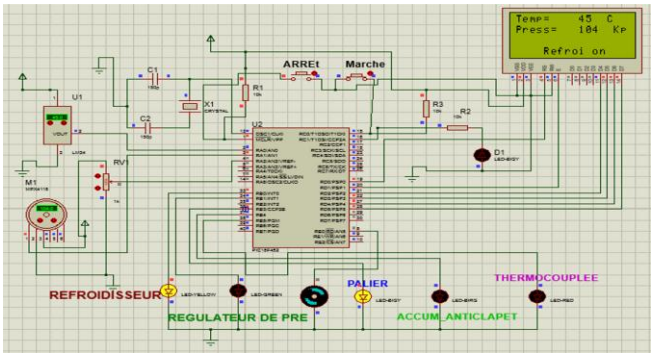


Fig.14 illustrates the simulation of the system.

Fig. 14. The simulation of application (case study 1)

2) Adaptation rules of SART method: We have established adaptation rules of the incremental method associated with SART:

a) Context Diagram

Rule 1: Each increment becomes a functional process numbered 0.

Rule 2: Data streams of each increment become input data for each process.

Rule 3: Results of each increment become sorties data streams for each functional process, or transformed for a given event.

Rule 4: Constant data types (standard liquid temperature) and the data must be recorded for each increment become storage units.

Rule 5: Entities outside of systems for each increment become endings (Terminals boundary).

b) Preliminary Diagram

Rule 1: If the increment requires functionality of pilotage then the process becomes a control process.

Rule 2: Increment is divided into several functions each function becomes a functional process numbered from 1 to n.

c) Decomposition Diagram

Rule 1: Each increment is decomposable becomes a decomposable process numbered X.Y or not decomposable is a primitive

B. Case study 2: Triaxial Appartus system

The triaxial test is one of the most versatile and widely performed geotechnical laboratory tests, allowing the shear strength and stiffness of soil and rock to be determined for use in geotechnical design. Advantages over simpler procedures, such as the direct shear test, include the ability to control specimen drainage and take measurements of pore water pressures. Primary parameters obtained from the test may include the angle of shearing resistance φ, cohesion C, and undrained shear strength Cu, although other parameters such as the shear stiffness G, compression index Cc, and permeability K may also be determined [**19].**

Fig.15 illustrate trixial appartus system:

Fig. 15. An overwiew of triaxial appartus system

The various realizable types of test are:

- Test UU (Unconsolidated-undrained): test unconsolidated not drained carried out on saturated material or not.
- Test CU (Consolidated-undrained): consolidated test not drained on saturated material or not.
- Test CU+u (Consolidated-undrained): consolidated test not drained on material saturated with measurement of the pore water pressure.
- Test CD (Consolidated-drained): consolidated test drained on saturated material.

The test apparatus comprises: a triaxial cell, a compression capacity of press 50 kn, and a measuring system (force sensor, displacement sensor, pressure sensor and a pore burette.)

The measurement Chain :

Our case study is available in the soil laboratory at the Department of Civil Engineering, it is often implied by the name, an automatic data acquisition system on the test performed. This system generally comprises various electronic sensors, an analog-digital converter and finally to a centralized computer acquisition. In our case, the electrode is "manual" as opposed to automatic. The operator must read the various sensors to derive the desired measurement.

Increments proposed

Increment 1: Data acquisition unit.

Increment 2: Display and acquisition software.

1) Experimenting methodology on a Case study 2: In this section we presented the experimenting of the second case study: triaxial apparatus system and illustrates the different phases of our developed design methodology. The design process started with the construction of a model using UML/MARTE.

Diagrams used in the model are Class diagram, Decomopsition diagram.

For the development of case study, Modelio tool **[18]** is used. The Modelio is a development of Softeam group and provides an open source tool for development and maintain of MDA for UML through the profile technique. Modelio supports several UML diagrams, as well as additional diagrams such as Business Process, Requirement, SysML or Enterprise Architecture diagrams.

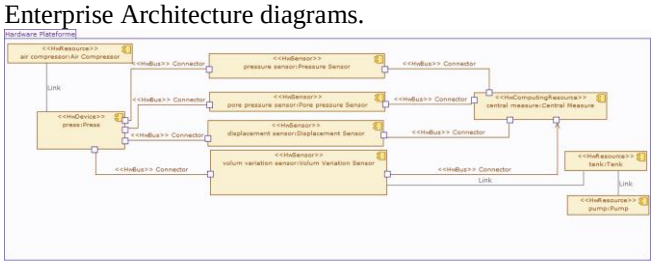


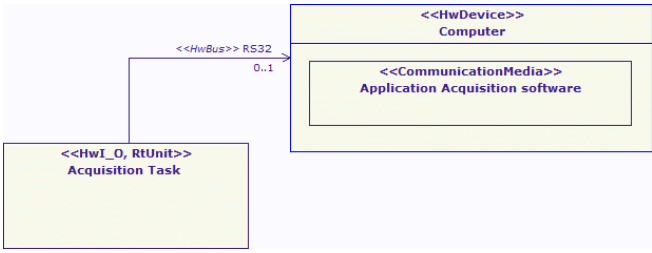
Fig. 16. Hardware plateform of triaxial appartus

We first illustrate the global structure of the triaxial apparatus system as illustrated in Fig.16, using a component diagram.

Our commitment to use MARTE HRM stereotypes here as the system is basically not traditionally hardware in the sense as it consists of electronic, electric and automotive components.

In the fig.16, the following nodes are present:

HwResource Air Compression,
HwDevice Press,
HwSensor Pore Pressure Sensor,
HwSensor Pressure Sensor,
HwSensor Displacement Sensor,
HwSensor Variation Sensor,
HwComputingResource CentralMeasure,
HwResource Tank,
HwResource Pump,



- **Specification Step (increment 1)**

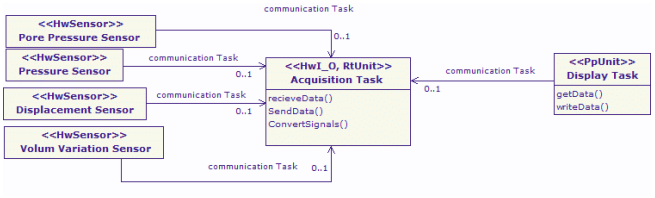


Fig. 17. Acquisition Task (Increment 1)

In Fig.17, the UML class diagram illustrates the communication flows between the different tasks of the execution platform.

- **Design step(increment 1)**

Fig. 18. Internal block structure of acquisition module

In the Fig.18, we first illustrate the internal block structure of the acquisition module. Which consists of an input InData port and an output OutData port.

- **Implementation step(increment 1)**

With respect to the environnent, we use also the microcontroller. Fig.19 present a simulation of my application.

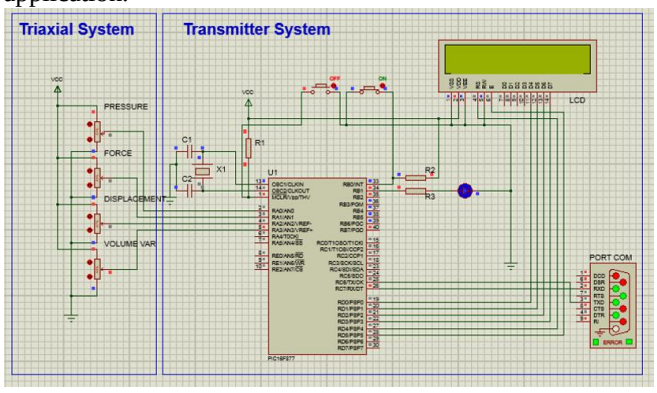


Fig. 19. the simulation of appliction

- **Specification Step (increment 2)**

Fig.20 illustrates the specification of increment 2 of software acquisition, we need an application for the reception of the data and compte the diffrents calculations,and a RS32 cable linked between the computer and acquisition unit.

Fig. 20. Class Diagram (increment 2)

2) Adaptation rules of MARTE profile: We have established translations rules of the UML/MARTE associated with c-microcontroller using the Sequences diagram.

Rules Translation

Rule 1: Each message of interaction becomes a sub-program.

Rule 2: Each repetitive structure becomes a variable, which corresponds to the number of repetition.

Rule 3: Each alternative structure becomes also an alternative structure with the same parameters.

Rule 4: Each observation of time becomes a variable.

Rule 5: Each time constraint becomes a condition treated by an alternative instruction.

Rule 6: Each object becomes a record structured by fields of specific types to store various information of the interaction between objects as well as the results of treatments and calculations.

V. DISCUSSION

This methodology allows gradually deploy functionality in a live environment to reduce the risk of a big deployment, when the system is analyzed as a whole, de-signed as a whole, implemented as a whole and tested as a whole .Feature interactions are often recognized in later development phases and it is very difficult, expensive and time-consuming to solve such kinds of problems . Another reason for applying our methodology is that teams can work more effectively.

On the other hand, our methodology is applicable when the developer system is a complex, contains at least three new complex increments, but if the system simple and contains a small functionalities, then this process does not work.

VI. CONCLUSION

In this paper, we proposed methodology of development based in incremental model for application complex real time and embedded systems.

The paper presents its contributions by proposing an effective subset of activities, forming the basis of our methodology and proposes set of concepts to increase quality of system developed, decrease complexity of system and promote synergy between the different teams working at different domain aspects of the global system in consideration.

Our methodology could inspire future researches of development RTES and may eventually aid in their evolution. Finally, the different activities and concepts and associated diagrams in the methodology have been illustrated in two case studies related to a hydrostatic bearing lubrication system and triaxial apparatus system.

VII. ACKNOWLEDGEMENT

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Real-time vibration control of rigid rotors using controlled supply pressure hydrostatic squeeze film dampers

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***Abstract*—the aim of this research is to study the Real-time control vibration of rigid rotor using controlled supply pressure hydrostatic squeeze film dampers. A linear model of the hydrostatic squeeze film damper has been developed in order to study the effect of the supply pressure on the dynamic behaviour of a rigid rotor. A new control system is proposed to reduce the transient response of the rotor using controlled supply pressure in order to control stiffness hydrostatic bearings. The results show that it is possible to effectively monitor the supply pressure and the dynamic characteristics of the fluid inside the hydrostatic squeeze film dampers for a better control of rigid rotor vibration and bearing transmitted forces.**

***Keywords*—** *Real time control vibration, hydrostatic journal bearing, linear dynamic behaviour, Squeeze film dampers, rotor dynamic*

XVII. INTRODUCTION

Many researchers have studied the effects of hydrostatic squeeze film dampers in order to use it as a device for actively controlling rotors. Burrowz et al. (1983) [1] have studied the possibility of controlling the pressure in an SFD as a mean for controlling rotating machinery. Mu et al (1991) [2] suggested an active SFD with a movable conical damper ring. San Andres (1992) [3] developed an approximate solution for the pressure field and dynamic force coefficients in turbulent flow, in a symmetric hydrostatic bearing with its journal centred within the bearing clearance. The model includes the effects of recess volume liquid compressibility and introduces the model for a HJB with end seals. The results of its investigation show that HJBs with end seals have increased damping, better dynamic stability characteristics than conventional HJBs. Braun et al (1994) [4] and (1995) [5] performed an extensive analysis of the variation in lubricant viscosity with pressure and temperature and also analyzed the flow pattern in the recesses. Hathout et al (1997) [6] summarized the modeling and control of hybrid squeeze film dampers for active vibration control of rotors exhibiting multiple modes. Sawicki et al (1997) [7] studied the effects of dynamic eccentricity ratio on the dynamic characteristic of a four–pocket, oil-fed, orifice-compensation hydrostatic bearing including the hybrid effects of journal rotation. Adams and Zahloul, (1987) [8] have invistegated the vibration of rotors by controlling the pressure in hydrostatic four-pad squeeze film dampers (SFDs). They showed that stiffness is quite controllable with supply pressure while damping is nearly insensitive to supply pressure changes using a linear method. Using a similar system, Bouzidane et al (2007) [9] studied the effects of film thickness, recess pressure and geometric configuration on the equivalent stiffness and damping of a four-pad hydrostatic journal bearing. Their results reveals that because of its higher stiffness, good damping and zero cross-coupling terms, the four-pad hydrostatic journal bearing has better dynamic characteristics and stability than the hybrid journal bearing. They found that an optimal equivalent stiffness of a four-pad hydrostatic journal bearing is obtained for a pressure ratio at the centered position ßo close to 0.67. Bouzidane et al (2008 -2013) [10-14] investigated the effect of electrorheological fluid, pressure ratio, supply pressure, viscosity, and rotational speed on the unbalance response and transmitted force of a rigid/flexible rotor supported by a four-pad hydrostatic squeeze film damper.

The objective of this research is to adapt supply pressure technology to hydrostatic squeeze film

damper in order to control the vibration of high speed rigid rotors. A linear model of the smart fluid hydrostatic squeeze film damper using controlled supply pressure has been developed. The transient amplitude–speed responses are calculated for a rigid rotor supported by a smart hydrostatic squeeze film damper. A new smart hydrostatic squeeze film damper is proposed to reduce the transient response of the rotor vibration by applying a control strategic on supply pressure, which results in modifying its stiffness hydrostatic bearings. The results show that it is possible to effectively monitor the supply pressure for a better control of rigid rotor vibrations and bearing transmitted forces.

XVIII. MATHEMATICAL MODELING

A cross section of a new three-pad hydrostatic squeeze film damper in the eccentric case is shown in Fig. 1. This figure shows a vertical rigid rotor supported by a hydrostatic squeeze film damper composed of three-pads. All pad-geometries are identical and equally spaced around the journal. The indices 1, 2 3 and 4 refer to the characteristics of the ith hydrostatic bearing flat pad, respectively. Each pad is fed by a capillary restrictor through a recess, which is supplied with an external pressure P_s.

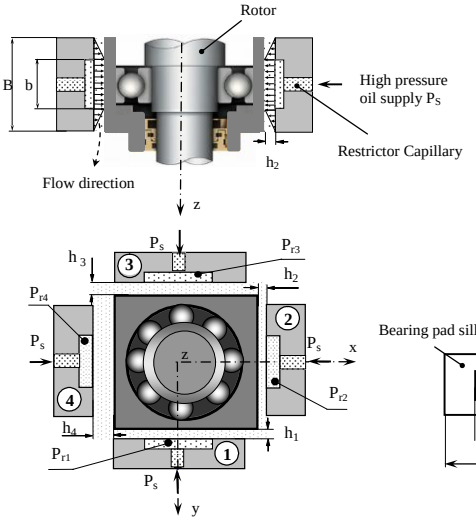


Fig.1: Hydrostatic journal bearing geometry and nomenclature

A Hydrostatic Squeeze Film Damper Characteristics

The calculation of the characteristics of the hydrostatic squeeze film damper can be obtained through the juxtaposition of three hydrostatic bearing flat pads (Fig.2). It is assumed that the fluid is incompressible and inertialess. The flow is laminar and the regime is steady state and isothermal.

B Reynolds Equation

For an incompressible, laminar, isoviscous, and inertialess fluid, the Reynolds equation may be written as [12]:

$$\frac{\partial}{\partial x_i}\left(\frac{\partial P_i(x_i,z_i,t)}{\partial x_i}\right)+\frac{\partial}{\partial z_i}\left(\frac{\partial P_i(x_i,z_i,t)}{\partial z_i}\right)=12\frac{\mu}{h_i^3}\dot{h}_i \quad (1)$$

Note that the cavitations are not neglected when the thickness film increasing.

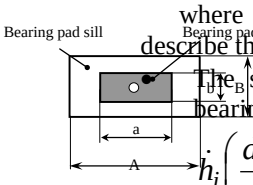
where:

- $0 \le x_i \le A$ and $0 \le z_i \le B$
- $P_i(x_i,z_i,t)$ is the hydrostatic pressure field of the i[th] hydrostatic bearing pad;
- h_i is the film thickness of the i[th] hydrostatic bearing pad ($h_i \neq f(x_i,z_i)$).
- (x_i, z_i, y_i) is the coordinate system used in the Reynolds equation, (i=1, 2 3, and 4).

- The film thickness h_i ($h_i = f(x,y) \neq f(x_i,z_i)$) is obtained as follows:

$$\begin{cases} h_1 = h_0 - y \\ h_2 = h_0 - x \\ h_3 = h_0 + y \\ h_4 = h_0 - x \end{cases} \quad (2)$$

where (x , y) is the coordinate system used to describe the rotor motion.



The squeeze velocity of the i[th] hydrostatic bearing pad is determined as follows: $\dot{h}_i\left(\frac{dh_i}{dt}\right)$.

$$\begin{cases} \dot{h}_1 = -\dot{y};\ \dot{h}_3 = \dot{y} \\ \dot{h}_2 = -\dot{x};\ \dot{h}_4 = \dot{x} \end{cases} \quad (3)$$

C Recess Pressure

The recess pressure for each hydrostatic bearing pad is determined by resolving the following flow continuity equation:

$$Q_{ri} = Q_{oi} \quad (4)$$

where:

- $$Q_{ri} = \frac{\pi d_c^4}{128 \mu l_c}(P_S - P_{ri})$$ (5)

- $$Q_{oi} = Q_{vi} + Q_{oxi} + Q_{ozi}$$ (6)

- $$Q_{vi} = S_r \dot{h}_i$$ (7)

- $$Q_{oxi} = 2\int_0^B dz_i \int_0^{h_i} u_{xi} dy_i \; ; \quad Q_{ozi} = 2\int_0^A dx_i \int_0^{h_i} u_{zi} dy_i$$ (8)

- $$u_{xi} = \frac{1}{2\mu}\frac{\partial P_i}{\partial x_i}(y_i - h_i)y_i \; ; \quad u_{zi} = \frac{1}{2\mu}\frac{\partial P_i}{\partial z_i}(y_i - h_i)y_i$$ (9)

where d_c is the capillary diameter and l_c is its length; Q_{vi} represents the squeeze flow of the i[th] hydrostatic bearing pad; Q_{oxi} and Q_{ozi} are the oil flow of the i[th] hydrostatic bearing pad in the x_i, and z_i directions, respectively, Q_{ri} represents the flow through a capillary restrictor-type hydraulic resistance; u_{xi}, u_{yi} and u_{zi} are the flow velocities in the x_i, y_i and z_i directions, respectively.

III ROTOR DYNAMICS BEHAVIOR

In order to reduce the excessive high amplitudes of forced vibrations and the forces transmitted to the base, caused by rotor imbalance and passage through critical speeds, a study on the dynamic behavior of a rotor supported by hydrostatic squeeze film dampers based on linear methods was conducted.

The equations of the rotor motion can be expressed in Cartesian coordinates as follows (Fig.2):

$$\begin{cases} m\ddot{x} = F_x + me_x \omega^2 \cos(\varphi) + me\ddot{\varphi}\sin(\varphi) \\ m\ddot{y} = F_y + me_y \omega^2 \sin(\varphi) - me\ddot{\varphi}\cos(\varphi) \end{cases}$$ (10)

where m is the mass of the rotor; e is the eccentricity; ω is the excitation frequency and F_x and F_y are the hydrostatic forces in the x and y directions, respectively. $\ddot{\varphi}, \dot{\varphi}$ and φ represent the angular acceleration, angular velocity and angular displacement respectively, which are given by:

$$\begin{cases} \ddot{\varphi} = \text{constant} \\ \dot{\varphi} = \dot{\varphi}_0 + \ddot{\varphi}\, t \\ \varphi = \varphi_0 + \dot{\varphi}_0 t + \frac{1}{2}\ddot{\varphi}\, t^2 \end{cases}$$ (11)

A Forces Hydrostatics Bearings

- *Linear model*

The linear model is based on a small displacement and small speed hypothesis [9], and it is presented by linearizing the behaviour around an equilibrium state. The linear fluid film forces on the three-pad hydrostatic squeeze film damper in Cartesian coordinates (O_j, x, y) are obtained as follows:

$$\begin{Bmatrix} F_x \\ F_y \end{Bmatrix} = -\underbrace{\begin{bmatrix} C_{xx} & C_{xy} \\ C_{yx} & C_{yy} \end{bmatrix}}_{[C_P]} \begin{Bmatrix} \dot{x} \\ \dot{y} \end{Bmatrix} - \underbrace{\begin{bmatrix} K_{xx} & K_{xy} \\ K_{yx} & K_{yy} \end{bmatrix}}_{[K_P]} \begin{Bmatrix} x \\ y \end{Bmatrix}$$ (12)

where $[C_P]$ and $[K_P]$ represent the total hydrostatic bearing damping matrix and stiffness matrix, respectively, which are given as follows [10]:

$$[C_P] = \sum_{i=1}^{i=3} C_{Pi} \begin{bmatrix} \cos^2(\gamma_i) & -\cos(\gamma_i)\sin(\gamma_i) \\ -\cos(\gamma_i)\sin(\gamma_i) & \sin^2(\gamma_i) \end{bmatrix}$$ (13)

$$[K_P] = \sum_{i=1}^{i=3} K_{Pi} \begin{bmatrix} \cos^2(\gamma_i) & -\cos(\gamma_i)\sin(\gamma_i) \\ -\cos(\gamma_i)\sin(\gamma_i) & \sin^2(\gamma_i) \end{bmatrix}$$ (14)

with

$$K_{Pi} = -\left(\frac{\partial F_{Pi}}{\partial h_i}\right)_0 \quad ; \quad C_{Pi} = -\left(\frac{\partial F_{Pi}}{\partial \dot{h}_i}\right)_0$$ (15)

where: K_{pi} and C_{pi} represent the stiffness and damping of the i[th] hydrostatic bearing pad, and F_{pi} is the hydrostatic force of the i[th] hydrostatic bearing pad. The partial derivatives are calculated numerically using the numerical differentiation method.

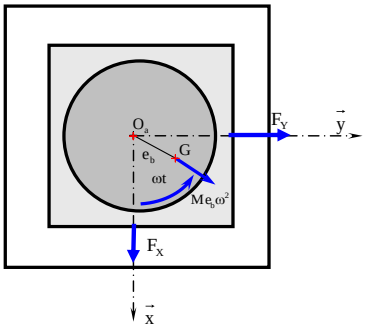


Fig2. Rigid rotor supported by four-pad HSFD

B. Solution procedure

The hydrostatic squeeze film damper effects on rotor dynamics are characterized by the hydrostatic forces generated by a pressure field. It must be noticed that these forces vary according to the position and velocity of the shaft center in the journal bearing. The calculation of the flow rate, vibratory responses and amplitude of transmitted forces due to a rotating unbalance vary depending on the rotational speed and are determined by resolving the equations of rotor motion (Eq. 10) using linear methods. The computed amplitudes are determined from direct numerical integration of the equations of motion using a step-by-step method. The hydrostatic forces are determined from equations (Eq. 12), which are based on the dynamic coefficients. The film thickness h_0 is determined by resolving the flow continuity equation from a given pressure ratio β_0 and using an iterative secant method, while the pressure is determined by resolving the flow continuity (Eq. [8]) by applying an iterative secant method.

The computation of the film thickness and recess pressure was performed using an iterative secant method after bounding the roots. The convergence tolerances of these computations were defined as follows:

- on the pressure: 0.01

$$\left(\left(\frac{P_{i,j}^{r} - P_{i,j}^{r-1}}{100\, P_{ri}} \right)_{\max} = 0.01 \right)$$

- on the film thickness: 10^{-6}
- on recess pressure: 10^{-6}

where $P_{i,j}^{r}$ represents the computed pressure at each mesh point (i,j) and r is the iteration number of the computation.

XIX. RESULTS AND DISCUSSION

As mentioned above, Figure 3 shows the transient response vibration amplitude versus time. It must be noticed from this figure that the envelope of displacements reveals the identification of critical speed (resonance). Not that the critical speed appears at 250 s. Fig. 4 presents the orbits around the critical speed. It can be seen from these results that the vibration amplitude come important around the critical speed.

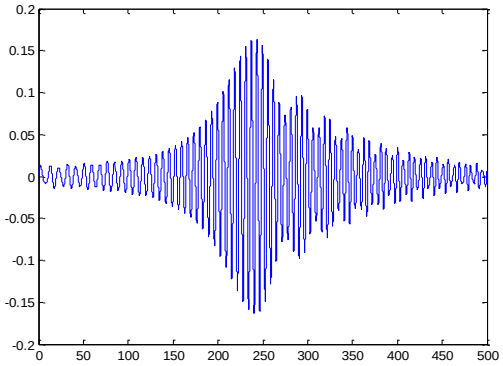


Fig.3 Transient response of the excitation versus time

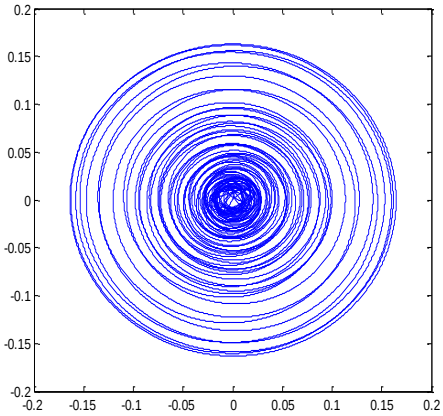


Fig.4 Orbits around the critical speed: X positions versus Y positions

Fig. 5 shows the effect of supply pressure on the responses due to rotational unbalance. This curve shows that when the pressure increases from 5 to 10 Bar, the amplitude and critical speed increase with an increase in supply pressure due to the increase in stiffness hydrostatic bearings. This leads an increase in rigidity zones since the critical increases with supply pressure.

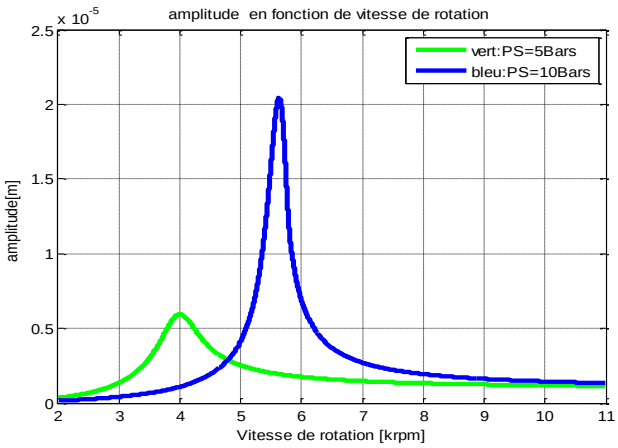


Fig.5 Amplitude versus rotational speed

A. Control method using controlled supply pressure

An of-on control system based on the control of supply pressure of a hydrostatic squeeze film damper can be developed to control rigid rotor vibration, reduce excessively high amplitudes of forced vibration and reduce the force transmitted to the bearing base. This control system functions by controlling supply pressure according to the operating speed of the rotor around the critical speed. An of-on control on supply pressure is proposed. Figure 6 demonstrates the use of the control system and the corresponding vibratory response. One can observe the effect of variations in the supply pressure on vibratory response versus speed and time in the HSFD. It can be seen from this results that it is possible to effectively monitor the supply pressure to reduce vibration amplitude when operating close to critical speed.

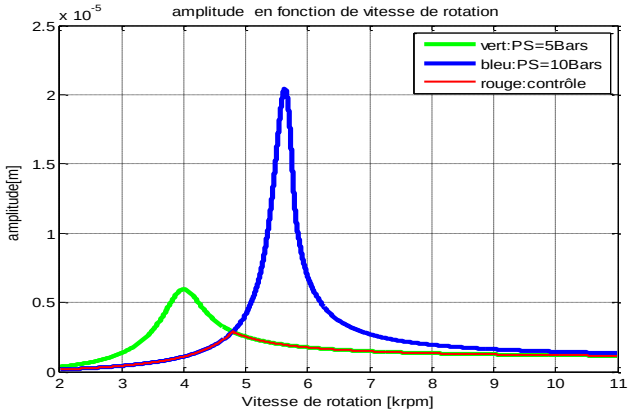


Fig.6 Control amplitude using controlled supply pressure

XX. CONCLUSIONS

Linear modeling of a hydrostatic squeeze film damper has been presented and applied in a control system to limit the vibration of high speed rigid rotor supported by a four-pad HSFD. The following conclusions can be obtained.

- Using controlled supply pressure of a hydrostatic squeeze film damper allows for achieving the objective to control the rotor vibration across the critical speeds. This effect is due to the fact that the stiffness hydrostatic bearing increases with an increase in supply pressure. Consequently the command law asked to control the supply pressure according to the operating speed of the rotor around the critical speed around the critical speed.
- The research shows that smart hydrostatic squeeze film dampers using controlled supply pressure has a promising potential future in vibration control of rigid/flexible rotor.

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Numerical study of the influence of turbulent regime on the load capacity of a hydrostatic journal bearing

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***Abstract*—The aim of the paper work is to investigate and predict the performance characteristics of four-pad hydrostatic journal bearings loaded between pads in both laminar and turbulent regimes. Linear modeling was performed using a numerical method to study the effects of Poiseuille Reynolds number, eccentricity, squeeze velocity and pressure ratio on the static and dynamic characteristics of hydrostatic journal bearings. The finite difference method has been used to solve Reynolds equation, based on Constantinescu's turbulent lubrication theory, governing the lubricant flow in film thickness of hydrostatic bearings. It assumed that the fluid flow is incompressible, isothermal, steady-state and inertialess fluid. The results presented in this paper are expected to be quite useful to bearing designers, in order to use it as a device for actively controlling rotors operating at high speeds.**

Keywords— hydrostatic journal bearings, laminar and turbulent regimes, squeeze velocity, eccentricity ratio and pressure ratio.

I- Introduction

The hydrostatic journal bearings have been selected as support elements in future cryogenic high-speed turbo machinery. They are often used in multi-application such as high speed turbomachinery; machine tools; machine control and the dispositive equipment test because of their capability of suppressing oil whirl that causes instability. Hydrostatic journal bearings have better dynamic characteristics due to their high stiffness; good damping at critical speeds their lubrication prevent contact of metal-metal even at zero speed.

Several researchers studied the performance of a hydrostatic journal bearing in the laminar regime [1-12]. The operation of high speed bearings and has a low viscosity meant that the flow regime is turbulent (the Reynolds number is above than 2000) as bearings for cryogenic applications operating at high speeds.

Several investigators [13-18] have proposed various theories to analyze the turbulent aspects applied in plain bearings. Of research efforts have been reported in the literature [19-27], focusing on the performance of multirecess hydrostatic journal bearings Hybrid operating in turbulent regime.

operating in a turbulent regime by considering various geometric shapes of recess. Their numerical simulation results indicate that the influence of turbulence is quite significant on the performance of a hybrid journal bearing system with different geometric shapes of recess However, the literature review revealed that the performance of a four-pad Hydrostatic Journal Bearing (HJB) loaded between pads in turbulent flow regime (Fig. 1) has not yet been investigated. This paper addresses this gap and presents an investigation of the effects of different flow regimes, squeeze velocity, eccentricity ratio and pressure ratio on the load-capacity, flow rate, damping ratio and dynamic characteristics of an orifice compensated four-pad HJB loaded between pads

II-Hydrostatic bearing description

Fig.1a shows a horizontal rigid rotor supported by a hydrostatic squeeze film damper composed of four-pad hydrostatic bearings. The indices 1, 2, 3 and 4 refer to the characteristics of the lower, left, upper and right hydrostatic bearing flat pad, respectively. Each pad is fed by an orifice restrictor through a recess, which is supplied with an external pressure P_s. All pad-geometries are identical and

equally spaced around the journal. The calculation of the characteristics of the hydrostatic journal bearings can be obtained through the juxtaposition of four hydrostatic bearing flat pads. It is assumed that the fluid is incompressible and inertialess. The flow is laminar and the regime is steady state and isothermal.

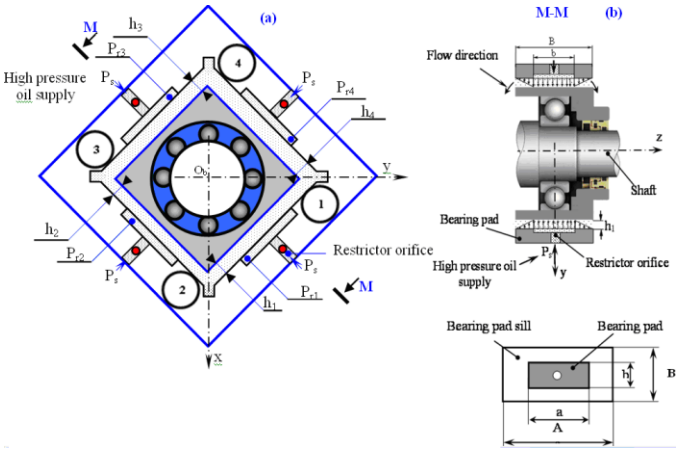

Fig1: Four-pad hydrostatic journal bearings loaded between pads

III-Reynolds Equation

Pressure distribution P_i (x_i, z_i,t), in the clearance space between runner and pad-bearing (Fig.2), can be governed by Reynolds equation. This equation can be solved numerically by applying the centered finite differences method, or analytically for specific cases such as infinitely long or short bearings. If we consider that there is no slip between the fluid and pad bearing, the boundary conditions associated with the speed will be as follows (Fig. 2):

- On flat pad: $U_{1i}=0$; $V_{1i}=0$ and $W_{1i}=0$ (1)
- On runner: $U_{2i}=0$; $V_{2i}=\dot{h}_i$ and $W_{2i}=0$ (2)

where $U_{1i}; V_{1i}$ and W_{1i} are the speeds of the surface of the i^{th} hydrostatic bearing pad, and $U_{2i}; V_{2i}$ and W_{2i} are the speeds of the surface of the runner; $\dot{h}_i$ is the squeeze velocity of the i^{th} hydrostatic bearing pad (i =1, 2 , 3 and 4);

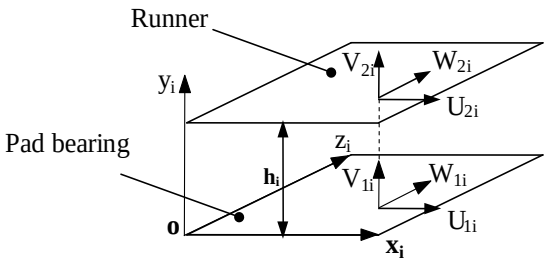

Fig.2: Boundary conditions of hydrostatic squeeze film dampers.

With these boundary conditions, and for an incompressible, isoviscous, and inertialess fluid, the modified Reynolds equation proposed by Constantinescu [15-19], for Poiseuille flow, may be written as:

$$\frac{\partial}{\partial x_i}\left(\frac{h_i^3}{\mu}G_x\frac{\partial P_i(x_i,z_i,t)}{\partial x_i}\right)+\frac{\partial}{\partial z_i}\left(\frac{h_i^3}{\mu}G_z\frac{\partial P_i(x_i,z_i,t)}{\partial z_i}\right)=\frac{\partial h_i}{\partial t} \quad (3)$$

Where: G_x and G_y are coefficients dependent on the Reynolds number. According to the preponderant flow, Constantinescu propounds the following expressions [17, 18, and 28]:

- For laminar flow:

$$K_p=12; \quad \text{if } R_p<\Re_{pi}; \quad (4)$$

- For transition flow:

$$K_p=12+\frac{(K_{pm}-12)(R_p-\Re_{pi})}{\Re_{ps}-\Re_{pi}}; \quad \text{if } \Re_{pi}<R_p<\Re_{ps} \quad (5)$$

Where: $K_{pm}=a_p\Re_{ps}^{bp}$

- For turbulent flow:

$$K_p=K_{pm}=a_pR_p^{bp}; \quad \text{if } R_p>R_{ps} \quad (6)$$

Where:

$$\Re_{pi}=1000; \Re_{ps}=2\Re_{pi}$$

$$a_p=0.197; b_p=0.681 \quad \text{for } R_p\le 100000$$

$$R_p=\rho\frac{V_{pm}\,h}{\mu}$$

Where: a_p and b_p are coefficients dependent on the Poiseuille Reynolds number value; R_p is the Poiseuille Reynolds number based on the fluid mean velocity produced by the hydrostatic pressure gradients; V_{pm} is the fluid mean velocity and h is the film thickness.

Thus, due to hydrostatic pressure gradient, the modified turbulence coefficients G_x and G_z can be obtained by:

$$G_x=G_z=1/K_p \quad (7)$$

III-1 Carrying Load Capacity

The integration of pressure over the bearing area yields the following load capacity result

$$W_{Pi}=\int_s P_i\,ds \quad (8)$$

For the calculation of the load considering the method by numerical integration or method called Trapeze:

$$W=\frac{1}{4}[P_i(1,1)+P_i(1,N)+P_i(M,1)+P_i(M,N)]\Delta x\Delta z+\frac{1}{2}\left[\sum_{I=2}^{M-1}(P_i(I,1)+P_i(I,M)\right]\Delta x\Delta z$$
$$+\frac{1}{2}\left[\sum_{J=2}^{N-1}(P_i(1,J)+P_i(M,J)\right]\Delta x\Delta z+\sum_{J+2}^{N-1}\sum_{I=2}^{M-1}P_i(I,J)\Delta x\Delta z \quad (9)$$

The fluid film forces on the journal may be written as:

$$\begin{cases} W_x = -\left(\left(F_{P1}+F_{P2}\right)-\left(F_{P3}+F_{P4}\right)\right)sin(\pi/4) \\ W_y = -\left(\left(F_{P1}+F_{P4}\right)-\left(F_{P2}+F_{P3}\right)\right)sin(\pi/4) \end{cases}$$

(10)

Flow rate requirement

The Recess Pressure is determined from the resolution of the flow continuity equation as follows:
For i=1 and 3

$$\mathrm{Q_{Oi}} = \mathrm{Q_{OXi}} + \mathrm{Q_{OYi}} + \mathrm{Q_{Vi}}$$

(11)
Where

$$\mathrm{Q_{OXi}} = 2\int_0^B \mathrm{dZ}\int_0^{h_i} \mathrm{U_{Xi}\,dy}\,;\ \mathrm{Q_{OZi}} = 2\int_0^A \mathrm{dX}\int_0^{h_i} \mathrm{U_{Zi}\,dY};$$

(12)

$$\mathrm{U_{Xi}} = \frac{1}{2\mu}\frac{\partial \mathrm{P}_i}{\partial \mathrm{X}}(\mathrm{y}-\mathrm{h_i})y;\ \mathrm{U_{Zi}} = \frac{1}{2\mu}\frac{\partial \mathrm{P}_i}{\partial \mathrm{Z}}(\mathrm{y}-\mathrm{h_i})y$$

And for i=2 and 4

$$\mathrm{Q_{Oi}} = \mathrm{Q_{OYi}} + \mathrm{Q_{OZi}} + \mathrm{Q_{Vi}}$$

Where

$$\mathrm{Q_{OYi}} = 2\int_0^B \mathrm{dZ}\int_0^{h_i} \mathrm{U_{Yi}\,dX}\,;\ \mathrm{Q_{OZi}} = 2\int_0^A \mathrm{dY}\int_0^{h_i} \mathrm{U_{Zi}\,dX}\,;$$

(13)

$$\mathrm{U_{yi}} = \frac{1}{2\mu}\frac{\partial \mathrm{P}_i}{\partial \mathrm{Y}}(\mathrm{y}-\mathrm{h_i})y;\ \mathrm{U_{Zi}} = \frac{1}{2\mu}\frac{\partial \mathrm{P}_i}{\partial \mathrm{Z}}(\mathrm{y}-\mathrm{h_i})y$$

Where u_{xi}, u_{Yi} and u_{Zi} are the flow velocities in the x, y and z directions respectively.

$$\mathrm{Q_{Vi}} = S_a h_i$$

(14)
Where Q_{Vi} represents the squeeze flow of the i^{th} hydrostatic bearing pad (i = 1, 2, 3 and 4)
The flow through a capillary (Used when the flow is laminar) is governed by

$$\mathrm{Q_R} = \frac{\pi \mathrm{d_C^4}}{128\mu L_C}(\mathrm{P}_S - \mathrm{P1})$$

(15)
The flow through an orifice is governed by:

$$\mathrm{Q_{Ri}} = \frac{\pi \mathrm{C_d d_0^2}}{4}\sqrt{\frac{2}{\rho}(\mathrm{P}_S - \mathrm{P1})}$$

(16)
Where d_0 is the orifice diameter and C_d is the discharge coefficient.

Parameter C_d is a function of the Reynolds number, Re Typically, it varies in a nonlinear fashion from Cd=0.3 for Re=2 to C_d=0.7 at Re=100 and drops to about C_d=0.6 for higher Re values.
Flow rate requirement
The total volumetric flow rate that must be supplied to the hydrostatic squeeze film dampers is:

$$Q_T = \sum_{i=1}^{4} Q_{oi} = Q_{o1} + Q_{o2} + Q_{o3} + Q_{o4}$$

(17)

III-2 Dynamic characteristic

The single pad linearized stiffness and damping coefficients of the hydrostatic bearing pad may thus be obtained by

$$\mathrm{K_{P1}} = -\left(\frac{\partial \mathrm{W_{P1}}}{\partial h_1}\right)_0$$

(18)

$$\mathrm{C_{P1}} = -\left(\frac{\partial \mathrm{W_{P1}}}{\partial \dot{h}_1}\right)$$

(19)
A similar approach can be extended to the calculation of the other hydrostatic bearing pads:

$$\mathrm{K_{P2}} = -\left(\frac{\partial \mathrm{W_{P2}}}{\partial h_2}\right)_0, \mathrm{K_{P3}} = -\left(\frac{\partial \mathrm{W_{P3}}}{\partial h_3}\right)_0, \mathrm{K_{P4}} = -\left(\frac{\partial \mathrm{W_{P4}}}{\partial h_4}\right)_0$$

(20)

$$\mathrm{C_{P2}} = -\left(\frac{\partial \mathrm{W_{P2}}}{\partial \dot{h}_2}\right), \mathrm{C_{P3}} = -\left(\frac{\partial \mathrm{W_{P3}}}{\partial \dot{h}_3}\right), \mathrm{C_{P4}} = -\left(\frac{\partial \mathrm{W_{P4}}}{\partial \dot{h}_4}\right)$$

(21)

VI-Results and discussion
In this section, we study the influence of Poiseuille Reynolds number, eccentricity ratio, squeeze velocity and pressure ratio on the dimensionless static load capacity

- Dimensionless load capacity

$$\overline{\mathrm{W}} = \overline{\mathrm{W}}_{\mathrm{X}} = \mathrm{W_x}/(\mathrm{S_p\ P_s});\ \overline{\mathrm{W}}_{\mathrm{yy}} = 0$$

Fig. 3 shows the effect of Poiseuille Reynolds numbers and pressure ratio on the dimensionless

load capacity for a squeeze velocity of 0.001 m/s and an eccentricity ratio of 0.2.
This figure indicates that the dimensionless load capacity increases with an increase in Poiseuille Reynolds numbers during the increase of pressure ratio.

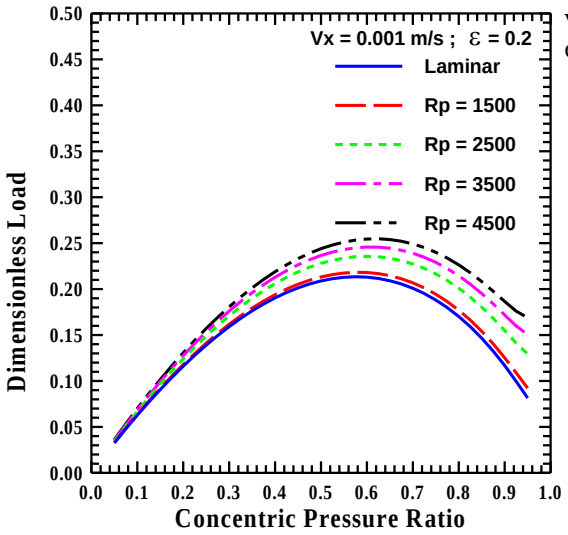

Fig3: Variation of load versus pressure ratio for different value of Reynolds number.

Fig.4 shows the effects of the eccentricity ratio and pressure ratio on the dimensionless static load capacity for a Poiseuille Reynolds number value of 2500 and a zero squeeze velocity. We note that the increase of eccentricity ratio increase the dimensionless static load capacity. This increase can be explained by the increase of hydrostatic forces due to the decrease of film thickness which increase the pressure in recess and land bearing.

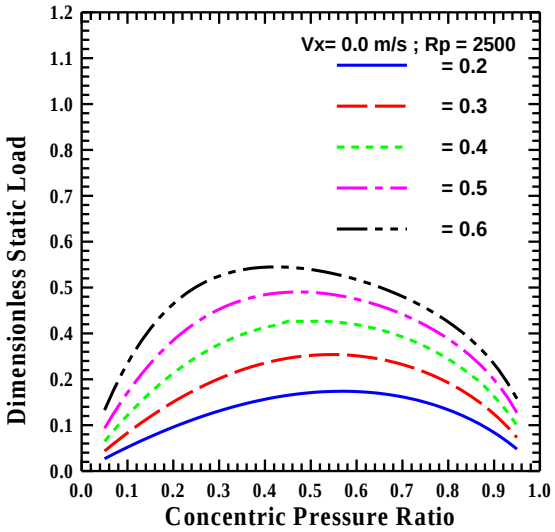

Fig4: Variation of load versus pressure ratio for different value of eccentricity ratio.

Fig.5 shows the effects of the squeeze velocity and pressure ratio on the dimensionless load capacity, for a Poiseuille Reynolds number value of 2500 and an eccentricity ratio of 0.2. We note that that the increase of squeeze velocity, from 0.001 to 0.01 m/s, increases significantly the dimensionless load capacity due to the increase of hydrostatic forces. It must be noticed that when the pressure ratio is higher than 0.9, the increase of the squeeze velocity results a very large dimensionless load capacity.

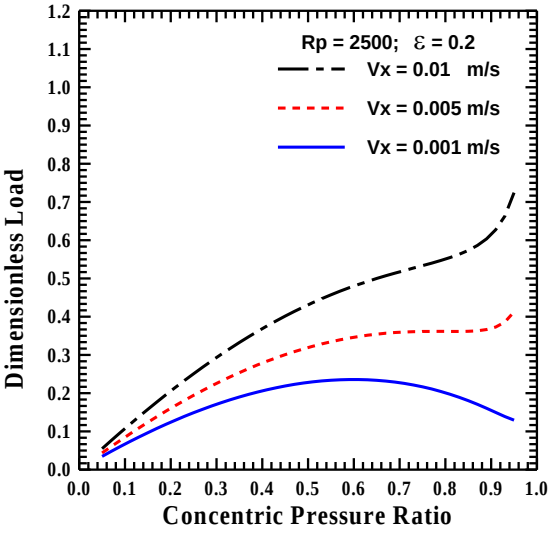

Fig5: Variation of load versus pressure ratio for different value of squeeze velocity.

V-Conclusion

The result obtained from a numerical model has been developed to study the effect of the Poiseuille Reynolds number; eccentricity and squeeze velocity on the dimensionless static load capacity of a hydrostatic journal bearing can be summarized as follows:

- An increase in Poiseuille Reynolds, eccentricity ratio and squeeze velocity lead to a significant increase of the load capacity due to the increase of pressure in recess and land bearing. However, there are no effects of Poiseuille Reynolds and squeeze velocity on the flow rate;
- It must be noticed that the load capacity have an optimum value with respect to pressure ratio;

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Solving Non Separable Convex Quadratic Programming Problems

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Abstract: *The aim of this paper is to present a new method for solving non-separable quadratic problems. In a first step we transform the non-separable quadratic problem in a separable quadratic problem equivalent. In a second step we solve the quadratic problem separable by the method of projection. The principle of this method is to calculate the critical point, if it is a feasible solution then this is the optimal solution. Otherwise, we construct a new feasible set by a homographic transformation on which we project the transformed critical point and we give the optimal solution belonging to the feasible set of the original problem. Note that the resolution is done directly on the primal separable quadratic problem and not on the linear problem as do several methods.*
The method is purely analytical and avoids the thorny problem of the choice of the initial solution.

Keyword: *Non Separable Quadratic Programming, Concave maximizing, Eigen values, Projection Method, Homographic Transformation.*

I. INTRODUCTION

The separable quadratic programming (Stephen B. and V. Lieven , 2004.) is very important in industry and finance. Non separable problems are traditionally solved by linear programming techniques (Hillier and Lieberman , 2001). In some others cases an allocation problem is formulated as a nonlinear constrained optimization problem and solved by a quadratic programming method (Gill et al. , 2002). Other approaches (Friedlander & all. 2012), prefer the method of semi- interior, and the method can be interpreted as an adjustment to the proximal point of primal-dual problems. The convergence problem has been studied in several articles including (Delbos F. Gilbert and J. Ch , 2003). On the other uses the modified Lagrange method (S. Ketabchi all . & 2009).

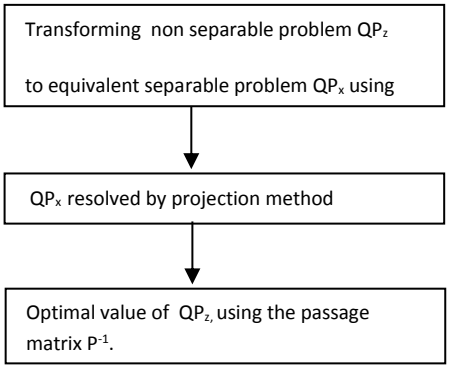
This article describes a new method based on the transformation of a non-separable quadratic programming problem in a separable equivalent problem. This coordinate transformation uses the Gauss pivot method to make the diagonal matrix representing the quadratic term of the objective function. Once we got equivalent problem, we apply it our quadratic programming algorithm based on the projection method.

Problem Formulation

The Matrix form of our non-separable problem is:

$$(\mathrm{QP}_z)\begin{cases}\max\ f(z)=c'z-z'Hz\\ Az\le b\\ 0\le z\le u\end{cases}.$$

The following schema shows the steps of resolution:



Before making a change of variables based on the diagonaliza-tion of the matrix H, we recall the basics of the diagonalization.

II. TRANSFORMING NON SEPARABLE PROGRAMMING

Definition (Eigenvalues , eigenvectors)
A scalar λ *is an eigenvalue of the matrix* H *if and only if there exists a vector* $v\neq 0_{R^n}$, $Hv=\lambda v$; v *is called an eigenvector of the matrix associated with the eigenvalue* λ .

Theorem 1:

1. *Let* H *a matrix* $n\times n$. λ *is an eigenvalue of* H *if and only if* $\det\left(H-Id_{(n,n)}\right)=0_{R^n}$.

2. *If* λ *is an eigenvalue of* H *then solution* $v \neq 0_{R^n}$ *of* $\det\left(H - Id_{(n,n)}\right) = 0_{R^n}$ *is an eigenvector associated with* λ.

Theorem 2:

Let H *a symmetric matrix* $n \times n$. *Then there exists an orthogonal matrix* P *which diagonalizes* H

We give the theorem which transforms a quadratic form with cross terms (in a quadratic form with only squared terms $P'HP = D$).

Theorem 3:

Let $H = (q_{ik})_{n \times n}$ *a symmetric matrix of eigenvalues* $\lambda_1, \ldots . \lambda_n$ *and* P *an orthogonal matrix that diagonalizes* H. *Then the change in the coordinate* $z = Px$ *transforms* $\sum_{i,k} q_{ik} Z_i Z_k$ *to* $\sum_i \lambda_i x_i^2$.

The matrix P is the matrix of passage is the matrix consisting of the orthonormal eigenvectors associated with eigenvalues of H .

$$\left(\mathrm{QP_x}\right) \begin{cases} \max\ g(x) = cPx - x'Dx \\ APx \leq b \\ 0 \leq Px \leq u \qquad x \in X \end{cases}$$

where,

- $D = P'HP$ is a diagonal matrix consisting of positive real eigenvalues of the matrix H .
- X is a finite set of values resulting from the product of the matrix P and the vector u .

We transformed quadratic function f to canonical quadratic function g and then non-separable quadratic problem $\left(\mathrm{QP_Z}\right)$ is transformed to separable quadratic problem $\left(\mathrm{QP_x}\right)$.

The next step solves separable quadratic problem $\left(\mathrm{QP_x}\right)$.

III. SOLVING SEPARABLE QUADRATIC PROGRAMMING

A. *Projection Method*

For simplicity, we write the canonical separable quadratic problem

$$\left(\mathrm{QP_x}\right) = \begin{cases} \max\limits_{x \in \Omega}\ g(x) = \sum\limits_{i=1}^{n} \alpha_i x_i + \beta_i x_i^2 \\ \alpha_i \in R, \quad \beta_i < 0 \\ \Omega = \left\{\ x \in R^n : 0 \leq x \leq u \ \text{ and } \ Ax \leq b\ \right\} \end{cases}$$

Let $x^* = (x_i^*)_i = \left(\dfrac{-\alpha_i}{2\beta_i}\right)_i$;

$$y^* = (y_i^*)_i = \left(\frac{\alpha_i}{2\sqrt{-\beta_i}}\right)_i$$

$$y = (y_i)_i = \left(\sqrt{-\beta_i}\, x_i\right)_i;$$

and

$$\underset{x \in \Omega}{Max}\, g(x) = g(\bar{x}); \ \ \bar{x} = (\bar{x}_i)_i \in \Omega.$$

The following theorem proves the algorithm of projection method described in this paper.

Theorem 4 : There exists a closed bounded convex set Ω' of R^n, and a vector $y_0 = (y_{0i})_i \in \Omega'$, such that the following statements are satisfied:

1. $\underset{x \in \Omega}{Max}\, g(x) = g\left(x^*\right) - \left\|y^* - y_0\right\|^2$;
2. $\left\|y^* - y_0\right\| = \inf\limits_{y \in \Omega'} \left\|y^* - y\right\|$;
3. $\bar{x}_i = \dfrac{y_{0i}}{\sqrt{-\beta_i}} \ \ \forall i$.

Proof:

For every $x \in \Omega$, let $\Delta g_i = \left(\alpha_i x_i^* + \beta_i x_i^{*2}\right) - \left(\alpha_i x_i + \beta_i x_i^{\ 2}\right)$. Then

$$\Delta g_i = \alpha_i \left(\frac{-\alpha_i}{2\beta_i}\right) + \beta_i \left(\frac{-\alpha_i}{2\beta_i}\right)^2 - \alpha_i x_i - \beta_i x_i^2$$

$$= \beta_i \left(x_i + \frac{\alpha_i}{2\beta_i}\right)^2 = \beta_i \left(x_i - x_i^*\right)^2.$$

But $g\left(x^*\right) - g(x) = \sum_{i=1}^{n} \Delta g_i$

$g\left(x^*\right) - g(x) = \sum_{i=1}^{n} -\beta_i \left(x_i - x_i^{\bullet}\right)^2$ for all $x \in \Omega$,

Therefore,

$$\inf_{x\in\Omega}\left(g\left(x^*\right)-g(x)\right)=\inf_{x\in\Omega}\left(\sum_{i=1}^{n}-\beta_i\left(x_i-x_i^{\bullet}\right)^2\right)$$

can be written in the following form:

$$g\left(x^*\right)-\operatorname*{Max}_{x\in\Omega}g(x)=\inf_{x\in\Omega}\sum_{i=1}^{n}\left(\sqrt{-\beta_i}\left(x_i^*-x_i\right)\right)^2$$

$$=\inf_{y\in\Omega'}\sum_{i=1}^{n}\left(y_i^*-y_i\right)^2.$$

Let

$$\Omega'=\left\{\ y=(y_i)_i\in R^n : y_i=\sqrt{-\beta_i}\,x_i, x=(x_i)_i\right.$$

, because

$$\inf_{y\in\Omega'}\sum_{i=1}^{n}\left(y_i^*-y_i\right)^2=\left\|y^*-y_0\right\|^2, y_0\in\Omega'.$$

Thus $\operatorname*{Max}_{x\in\Omega}g(x)=g\left(x^*\right)-\left\|y^*-y_0\right\|^2$, hence property (1).

Because $\inf_{y\in\Omega'}\left\|y^*-y\right\|^2=\left\|y^*-y_0\right\|^2$, then $\left\|y^*-y_0\right\|^2\le\left\|y^*-y\right\|^2$, for every $y\in\Omega'$.

This implies that $\left\|y^*-y_0\right\|\le\left\|y^*-y\right\|$, for every $y\in\Omega'$. We have therefore $\left\|y^*-y_0\right\|\le\inf_{y\in\Omega'}\left\|y^*-y\right\|$.

Because $y\in\Omega'$ then $\left\|y^*-y_0\right\|\ge\inf_{y\in\Omega'}\left\|y^*-y\right\|$; then $\left\|y^*-y_0\right\|=\inf_{y\in\Omega'}\left\|y^*-y\right\|$. Hence property (2).

The vector y_0 is the projection of the vector y^* onto the new convex Ω'. We have

$$\operatorname*{Max}_{x\in\Omega}\varphi(x)=g(\bar{x})=g\left(x^*\right)-\left\|y^*-y_0\right\|^2$$

$$=g\left(x^*\right)-\inf_{x\in\Omega}\sum_{i=1}^{n}\left(y_i^*-\sqrt{-\beta_i}\,x_i\right)^2$$

$$=g\left(x^*\right)-\sum_{i=1}^{n}\left(y_i^*-\sqrt{-\beta_i}\,\bar{x}_i\right)^2.$$ Hence property (3).

The transformation $T:\Omega\subset R^n\to\Omega'\subset R^n$, for each $x\in\Omega$, associating $T(x)=\Lambda x,\ \Lambda=\left(\sqrt{-\beta_1},.....,\sqrt{-\beta_n}\right)$ has as Jacobean matrix

$$\begin{bmatrix}\sqrt{-\beta_1} & 0 & \dots & 0\\ 0 & \dots & \dots & \dots\\ \dots & \dots & \dots & \dots\\ 0 & \dots & 0 & \sqrt{-\beta_n}\end{bmatrix}$$

Its determinant is $\prod_{i=1}^{n}\sqrt{-\beta_i}\neq 0$. Then it is conform.

Algorithm of computing the optimal solution of $(\mathrm{QP_x})$.

Algorithm

Initialization: matrix A, vectors b, c, alpha and beta.

If all $\beta_i = -1$ **then** $\Omega'=\Omega$ **else** build Ω' and compute the critical point

If $x^*\in\Omega$ **then** x^* is the Optimal solution. **STOP**.

else

begin

for i= 1 to n

begin

$$y^*=(y_i^*)_i=\left(\frac{\alpha_i}{2\sqrt{-\beta_i}}\right)_i$$

$$y_0=P_\Omega\left(y^*\right)=y^*-\frac{<y^*,a>-b}{\|a\|^2}a$$

$$\bar{x}_i=\frac{y_{0i}}{\sqrt{-\beta_i}}$$

end

If $\bar{x}\in\Omega$ then $\bar{x}$ is the Optimal solution ; compute $g(\bar{x})$ **STOP**.

else

change the supporting hyper plane separator

end.

Example

$$(\mathrm{QP}_z)\begin{cases}\max\ f(z)=69z_1+71z_2-15z_1^2-17z_2^2-2z_1z_2\\ 81z_1+50z_2\le 61\\ 17z_1+2z_2\le 105\\ 0\le z_1\le 3\\ 0\le z_2\le 2\end{cases}$$

It can be written as

$$H=\begin{bmatrix} -15 & -1 \\ -1 & -17 \end{bmatrix} \qquad c=\begin{bmatrix} 69 & 71 \end{bmatrix}$$

$$A=\begin{bmatrix} 81 & 50 \\ 17 & 2 \\ 1 & 0 \\ 0 & 1 \end{bmatrix} \qquad b=\begin{bmatrix} 61 \\ 105 \\ 3 \\ 2 \end{bmatrix}.$$

Begin by transforming the non-separable problem QP_z in separable problem QP_x.

The diagonal matrix is

$$D=\begin{bmatrix} -17.4142 & 0 \\ 0 & -14.5858 \end{bmatrix}$$

and the transition matrix is

$$P=\begin{bmatrix} 0.3827 & -0.9239 \\ 0.9239 & 0.3827 \end{bmatrix}$$

the constraint matrix A is transformed into

$$A'=A*P=\begin{bmatrix} 77.1913 & -55.7001 \\ 8.3534 & -14.9406 \\ 0.3827 & -0.9239 \\ 0.9239 & 0.3827 \end{bmatrix}.$$

The vector c is transformed into $c'P=\begin{pmatrix} 92.0006 & -36.5772 \end{pmatrix}$

$$(QP_x)\begin{cases} \max\ g(x)=c'Px-x'Dx \\ APx \le b \\ 0 \le Px \le u \qquad (x \in X) \end{cases}$$

And so we have to solve a separable quadratic programming

$$(QP_x)\begin{cases} \max g(z)=92.0006x_1-36.5772x_2-17.4142x_1^2 \\ 77.1913x_1-55.7001x_2 \le 61 \\ 8.3534x_1-14.9406x_2 \le 105 \\ 0.3827x_1-0.9239x_2 \le 3 \\ 0.9239x_1+0.3827x_2 \le 2 \end{cases}$$

The critical point is

$$x^*=\begin{cases} \dfrac{\partial f}{\partial x_1}(x_1,x_2)=-1.4905 \\ \dfrac{\partial f}{\partial x_2}(x_1,x_2)=2.7617 \end{cases}, \qquad x^* \notin \Omega,$$

because $x^*(1)<0$

It is therefore necessary to construct Ω' transformed Ω by the transformation T.

$$\Omega'=\left\{(x_1,x_2)\in R^2 / A2x \le b \qquad avec \qquad A2=A/sqrt(-D)\right\}$$

$$A2=A/sqrt(-D)=\begin{bmatrix} 18.4977 & -14.5845 \\ 2.0018 & -3.9120 \\ 0.0917 & -0.2419 \\ 0.2214 & 0.1002 \end{bmatrix}$$

$$Y^*=\begin{pmatrix} 11.0232 & -4.78867 \end{pmatrix}$$

is the transformed of the critical point x^*.

We recall the formula projection of a point y^* on a hyperplane $ay+b=0$:

$$y_0=P_{\Omega'}(y^*)=y^*-\frac{<y^*,a>-b}{\|a\|^2}a$$

Hyperplanes are here constraints of our problem,

therefore $y_0=P_{\Omega'}(y^*)=\begin{pmatrix} 3.9310 & 0.8032 \end{pmatrix}$.

The transition to $\bar{x}$ the optimal solution of the initial feasible set Ω is:

$$(\bar{x}_i)_i=\left(\frac{y_{0i}}{\sqrt{-\beta_i}}\right)_i=\begin{pmatrix} 0.9420 & 0.2103 \end{pmatrix}$$

The value of the optimal solution to our original problem (QP_z) is:

$$x_{opt}=\bar{x}\times P'=\begin{pmatrix} 0.9420 & 0.2103 \end{pmatrix}\times\begin{pmatrix} 0.3827 & 0.9239 \\ -0.9239 & 0.3827 \end{pmatrix}$$

$$=\begin{pmatrix} 0.1662 & 0.9508 \end{pmatrix}$$

$$\boxed{f(x_{opt})=62.8742}.$$

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Contribution by a hybrid algorithm to solve the multi-dimensional multiple-choice knapsack problem MMKP

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Abstract— In this paper, we approximately solve the multiple-choice multi-dimensional knapsack problem. We propose a mixed algorithm based on branch and bound method and Pareto-algebraic operations. The algorithm starts by an initial solution and then combines one-by-one groups of the problem instance to generate partial solutions in each iteration. Most of these partial solutions are discarded by Pareto dominance and bounding process leading at the end to optimality or near optimality in the case when only a subset of partial solutions is maintained at each step. Furthermore, a rounding procedure is introduced to improve the bounding process by generating high quality feasible solutions during algorithm execution. The performance of the proposed heuristic has been evaluated on several problem instances. Encouraging results have been obtained.
Keywords— combinatorial optimization, heuristics, knapsacks, branch and bound.

I. Introduction

In this article, we try to propose a resolution to approximate the problem of multidimensional knapsack multiple choice (MMKP).

The problem of multi bag back choice multidimensional MMKP is a special case of the general problem of the backpack, considered one of the combinatorial optimization problems most studied in recent years, because this problem has many practical applications [1].

The fundamental problem of the bag back to binary 0-1 considers element n, where each element has a value of v profit and cost of the proposed weight w resource.

The goal is to put the items in a backpack so that the capacity of the backpack resources is not

exceeded and the value added benefit of packaged items is maximized [2].

The MMKP is a variant of the complex problem of binary bag back 0-1, it is classified as a combinatorial optimization problem NP-hard [1]; where the items are listed in the classroom, the selected item will eliminate the choices of other objects belonging to the same class.

It is applied in many forms; in industrial or economic real world applications [1], such as space management or cutting.

It is a sub-problem to solve a more general problem. So it's resolution contributes to solving it.

Formally MMKP is to maximize the objective function (gain) at a number of capacity constraints and choice constraints[3].

The idea of the MMKP is to choose exactly one item from each class to maximize the value of total profit for this choice subject to resource constraints. Considering the decision variables x_{ij}

when j element of the i class is taken then it is equal to 1 or 0, the MMKP can be formulated in a linear program [4].

[2] II. DEFINITION OF MMKP PROBLEM

The MMKP problem is characterized by: - A vector of size m said capacity or resources R = (R_1, R_2, .., R_m)
- A set S = (S_1, ..., S_i, ..., S_n) to be divided into n disjoint classes such that for every pair (p, q) objects; such that: $p \neq q$; $p \leq n$ and $q \leq n$, we have $S_p \cap S_q = \emptyset$; and $S_1 U ... U S_{n-1} = S$.
Each class i; i = 1, .., n is number of objects of class i. we must seek to maximize an objective function that is a profit where ach object j of class i associated vij a positive profit and a weight vector $W_{ij} = (w_{ij}^1, w_{ij}^2 .., w_{ij}^m)$.

The goal is to assign the knapsack, exactly one and only one object per class with a maximum benefit without violating the capacity constraints [2].

The MMKP can be formulated in an Integer Linear Program (ILP) as follows: [7]

$$(MMKP)\begin{cases} Z(x) = \max \sum_{i=1}^{n}\sum_{j=1}^{r_i} v_{ij}x_{ij} & \\ \text{s.c.} \sum_{i=1}^{n}\sum_{j=1}^{r_i} w_{ij}^k x_{ij} \leq R^k, & k \in \{1,\ldots,m\} \\ \sum_{j=1}^{r_i} x_{ij} = 1, & i \in \{1,\ldots,n\} \\ x_{ij} \in \{0,1\}, & i \in \{1,\ldots,n\},\ j \in \{1,\ldots \end{cases}$$

Note that the variable x_{ij} is 1 if the object j of the class i is taken from the bag and is 0 otherwise. The constraints of type (1) are the capacity constraints. The constraints of type (2), called selection constraints, assure that each class of a single object must be selected. Authors are considered a variant that generalizes two other problems generalizing also the problem of bag-to-back: the problem of MDKP and the problem of MCKP, and recently MMMKP. The problem MMKP becomes a problem when there MCKP one capacity constraint, whereas if there is only one class of choice and constraints will no longer have reason to be then it becomes a MDKP problem [7].

Solving methods of MMKP differ from that of other variants of KP problem because the wording is different, and the process of resolution can be derived from the methods used for the other variants. [8]

This paper presents BPH, for Branch and bound Pareto-algebraic Heuristic. BPH is a heuristic based on Branch and Bound (B&B) and uses the principle of Pareto algebra.

III A branch and bound based heuristic

Discuss in this section, largely specific to the resolution of the problem of MMKP existing methods, they represent two broad approaches to resolution: heuristics or accurate, their derivatives are based on the characteristics of each that prove to be complementary. [9]

An exact method is characterized by the near certainty of achieving the optimal solution is theoretical but given the time of exponential calculation (2k) such that k is the number of objects) in the space of solutions of the problem. An approximate method known as heuristic consists in solving an optimization problem to reduce the search space resulting in reduced time to implementation; while not guaranteeing the optimality of the solution found [8] [13] [14].

The exact methods tell complete because it lists all the solutions; and approximate methods are called incomplete because it explores a subset of solutions. In the literature, there is very little accurate treating MMKP algorithms. These algorithms are based on branch and bound methods and differ in the valuation method used and the method of separation function. The first such algorithm was proposed by Khan et al. [10] It is based on the upper bound produced by the simplex method and then uses the method of Branch & Bound exploring the search tree by selecting the Best first (best first). The algorithm produces an optimal solution for instances of small and medium size [11].

As for the heuristic approaches, one of the first proposed heuristic is the one set by Moser [5] based on Lagrangian relaxation; Then comes the heuristic-based greedy algorithm proposed by Dantzig [8]; the generation of the column described in [1], it was enhanced by the concept of hybridizing with the connection to improve the quality of solutions Their concept converges to the same idea: first find a feasible solution for MMKP instance and iterate this calculation method by removing elements to improve the final solution[1].

Motivated by the success of branch and bound algorithm in exact methods and Pareto-algebra in approximate methods, we propose a heuristic based on a combination of the two aforementioned

approaches enhanced by a rounding procedure which can generate high quality feasible solutions during the search process.

IV HYBRID ALGORITHM

We propose a procedure based on the branch-and-bound (B&B) incorporating a modified method of B&B combined operations Pareto-algebraic version of hybrid algorithm; but does not guarantee the optimality of the solutions obtained. So the proposed approach we combine classical exact branch of B&B with the heuristic of Pareto algebra. The Branch and Bound use the separation algorithm and evaluation (Branch and Bound), so it guarantees an intelligent exploration of the field of solutions [2].

However the efficiency depends on how to choose to carry out the separation and evaluation. The principle of separation: The separation principle is to divide the problem into a number of sub-problems each with its set of feasible solutions. Resolving all sub-problems and taking the best solution found, it is guaranteed to have solved the original problem.
The separation principle is applied recursively to each of subsets as it contains several solutions.

Note: The process of separating a set stops when the following conditions are satisfied:

-knows the best solution of all;
-knows better than any of the solution set;
-knows all there are no feasible solution.
The Strategy applied:
The strategy is the rule for choosing the next summit to be separated from the set of vertices of the tree. Among the best known strategies course include:

[3] The depth-first: The exploration focuses on sub-problems obtained by the largest number of separations applied to the initial problem, that is to say the most distant peaks of the root (the highest depth). Rapidly obtaining a feasible solution (for problems where it is difficult to get a good heuristic) and the little space required memory are the benefits. The downside is the exploration of subsets which may be inauspicious to obtain an optimal solution.

[4] The breadth-first: This strategy facilitates the sub-problems obtained by the least separation problem of starting, that is to say the closest to the root apexes (depth the lowest).

[5] The best first: This strategy encourages the exploration of sub-problems with the smaller lower bounds.

The strategy directs research where the probability of finding a better solution is the largest. We use the following strategies: DFS, BFS and The Best first, the strategy will determine the next steps in terms of quality and optimal execution time. [2] In our algorithm, we choose the method of Best First reduce for the execution time.

The higher maximum Zsup is initialized, for each iteration of a branch of the tree, resulting Zbest maximum is compared to Zsup if above the Zsup retrieves the value of Zbest. [8]

The algebra of Pareto Using algebra Pareto in [11] was combined with another heuristic; but it is based on the basic concept of algebraic operations Pareto namely configurations dominated and infeasible are removed from the search space of the solution remains the only dominant. It overcomes the explosion of the space of possible combinations of the search tree of B & B [12].

The concept of the hybrid algorithm The algorithm begins by generating an initial solution and then combines the groups one by one instance of the problem to generate partial solutions to each iteration.
Most of these solutions are eliminated by the Pareto dominance; but also by the process of evaluation at the end leading to the optimal solution or a solution close to the optimum in the case where only part of the partial solutions is maintained at each step. In addition, a rounding procedure is introduced to improve the evaluation process by generating feasible solutions of high quality while running the algorithm. The performance of the heuristics should be evaluated on two types of bodies; namely regular and non-regular instances (Table 1 & 2).

Regular Instances	Number of CLASS	Number of CONTRAINTES	Number of objects in class	Total objects
I01	5	5	5	25
I02	10	5	5	50
I03	15	10	10	150
I04	20	10	10	200
I05	25	10	10	250
I06	30	10	10	300
I07	100	10	10	1000
I08	150	10	10	
I09	200	10	10	
I10	250	10	10	
I11	300	10	10	
I12	350	10	10	
I13	400	10	10	

Tab1 A regular Instances used

Irregular Instances	Number of CLASS	Number of CONTRAINTES	Tota objec
RTI07	10	5	23
RTI08	20	10	109
RTI09	30	10	158
RTI10	30	10	235
RTI11	30	20	208
RTI12	40	10	241
RTI13	50	10	295
INST21	100	10	565
INST22	100	20	538
INST23	100	30	541
INST24	100	40	584
INST25	100	10	871
INST26	100	20	842
INST27	200	10	1076
INST28	300	10	1643
INST29	400	10	2223
INST30	500	10	2704

Tab2 Irregular Instances used

For regular instances, they are among 13 instances. [10] The first six bodies are small and medium in which the optimal solutions are known their size. The remaining seven bodies are characterized by their large size, the number of class is of the order of 100 to 400 with the same number of constraints 10, note that their optimal solutions have not been proven. [1] As for non-regular instances, the number of classes is in the range 10 {discrete; 20, 30, 40, 50, 100; 200; 300, 400; 500}; the number of objects varies between 23 and more than 2,500 objects.

V THE PSEUDO-ALGORITHM OF BRANCH & BOUND – PARETO – HEURISTIC (BPH)

The algorithm is based on combining one-by-one groups of the MMKP instance using Pareto-algebra product operation as explained in figure 1. It is obvious that exact solution based on Pareto-algebra product cannot be considered for large instances.

As a first step, the algorithm tries to find Pareto points in each configuration set. Dominated configurations cannot contribute to an optimal solution of the MMKP instance.

Input : MMKP instance with a vector of configurtions S and a vector of capacity F
C_i, C_{i+1} configurations sets
Output : Z_{best} solution

- for all $A_i \in S$ do min(A_i)
- Z_{debut} = initial sol() // -∞
- Z_{best} = Z_{debut}
- Sort vector S in order to put groups with first items
- Initialize a set of partial solutions $A_{partial}$=S(1) and S= S – S(1)

6. for all $A_i \in S$ do
   combine $A_{partial}$ with configurations A_i
   eliminate discard any infeasible
   or dominated configuration from $A_{partial}$
   $A_{partial}$ = product sum min(C_i , C_{i+1} , F)
   for all configuration $\bar{a}_j \in A_{partial}$ do
   calculate bound value Z_{sup}
   if Z_{sup} + profit($\bar{a}_j$) ≤ Z_{best} then
   discard partial solution
   else
   if Z_{sup} + profit($\bar{a}_j$) >Z_{best} then
   Z_{best} = Z_{sup} + profit($\bar{a}_j$)
   apply best first search strategy to select
   A_{best} =best ($A_{partial}$)
7. Z= best configuration ($A_{partial}$)
   if Z > Z_{best} then Z_{best} =Z
8. return Z_{best}

Fig1 The Pseudo-algorithm BPH proposed

VI Computational results

The purpose of this section is to experimentally investigate the various aspects of BPH on standard benchmarks. We evaluate the performance of BPH compared to the state-of-the-art best results. The obtained results are also compared to those obtained when running one hour Cplex Solver v12.2 on the same set of instances. Our algorithms were coded in C++ and all experiments were done on a PC with a 2.13GHz Intel Pentium Dual Core CPU and 2GB of memory.

Regular instances					
#Inst	n	r_i	m	$\sum_{i=1}^{n} r_i$	Opt
I01	5	5	5	25	173
I02	10	5	5	50	364
I03	15	10	10	150	1602
I04	20	10	10	200	3597
I05	25	10	10	250	3905,7
I06	30	10	10	300	4799.3
Irregular instances					
#Inst	n	r_{max}	m	$\sum_{i=1}^{n} r_i$	Opt
RTI07	10	5	5	23	564
RTI08	20	10	10	109	6576
RTI09	30	10	10	158	7806.2
RTI10	30	20	10	235	7032
RTI11	30	20	20	208	6880
RTI12	40	10	10	241	11564
RTI13	50	10	10	295	10561

Table 1. Small to medium size test problem details

Regular instances					
#Inst	n	r_i	m	$\sum_{i=1}^{n} r_i$	Upper b.
I07	100	10	10	1000	24607.95
I08	150	10	10	1500	36904.41
I09	200	10	10	2000	49193.87
I10	250	10	10	2500	61486.30
I11	300	10	10	3000	73797.74
I12	350	10	10	3500	86100.45
I13	400	10	10	4000	98448.64
Irregular instances					
		r_{max}			
INST21	100	10	10	565	44315
INST22	100	10	20	538	42076
INST23	100	10	30	541	42763
INST24	**100**	**10**	**40**	**584**	**42252**
INST25	**100**	**20**	**10**	**871**	**44201**
INST26	**100**	**20**	**20**	**842**	**45011**
INST27	**200**	**10**	**10**	**1076**	**87650**
INST28	**300**	**10**	**10**	**1643**	**134672**
INST29	**400**	**10**	**10**	**2223**	**179245**
INST30	**500**	**10**	**10**	**2704**	**214257**

Table 2. Large size test problem details

The problems we considered are summarized in Tables 1 and 2. We tested a total of 30 instances corresponding to two groups: (i) regular instances with groups containing the same number of items.

We can draw several conclusions from these results.

First, the BPH results are competitive in terms of quality and running time especially those given in bold.

Second, in columns reporting the pure Cplex results with a time budget of one hour, we may conclude that hybrid heuristics outperform pure Cplex when given equal time budgets.

Third, the results we obtained with genetic algorithms are disappointing despite the use of several repair operators to deal with infeasible solutions generated by crossover operator.

In fact, we are persuaded that in the case of MMKP, any purely heuristic approach is doomed to fail. Hybridization with exact methods is better suited.

Finally, note that with BPH heuristic, we have only one parameter to adjust; the parameter L representing the number of partial solutions maintained at each iteration, while in all the state-of-the-art heuristics, there are several parameters to consider, and it is well known that when using approximate algorithms to solve optimization problems, different parameter settings lead to results of variable quality and the configuration of these parameters is a difficult task.

VII CONCLUSION

We started to implement the proposed algorithm to solve the problem of bodies own multidimensional multiple choice knapsack using a hybrid algorithm.

The algorithm is based primarily on the use of Pareto - a product that combines an all sectors of the MMKP instance at hand. Second, much of the generated partial solutions is rejected either by Pareto dominance or better by the exact method of Branch & Bound. A rounding procedure is used to generate realistic high quality solutions in the execution of the algorithm, and the improvement of the selection process.

Encouraging results are possible because we think it will provide high-quality solutions in a reasonable computation time, and can generate good solutions in a reduce due to rounding performed at each iteration of the algorithm execution time .

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