Parallel And Distributed Systems: Paradigms and Models
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Final Project
Autonomic Farm Pattern

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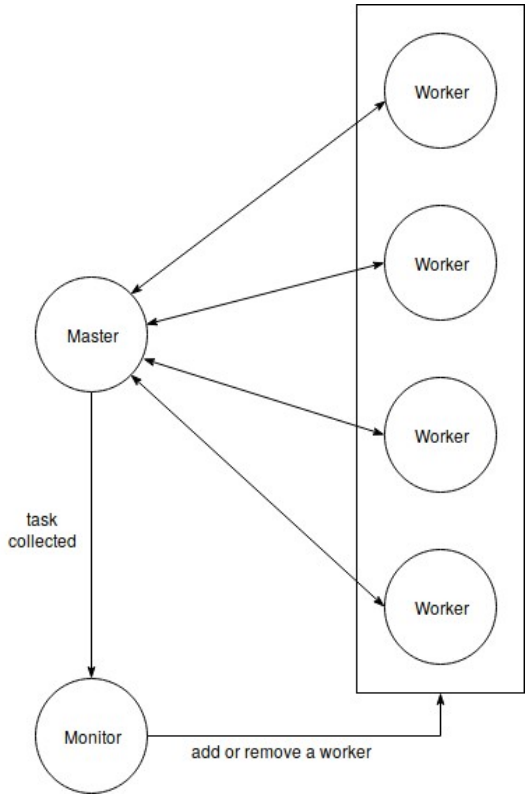
Introduction

In this report we will discuss about the implementation of the Autonomic Farm Pattern. First we will present the parallel architecture and the expected performances; then we will talk about the most important implementation choices and we will show the results of the experiments performed on the Xeon Phi KNL.
At the end we will discuss briefly about the FastFlow implementation.

Before starting it's important to discuss just one thing.
In the requirements was asked to take in input the expected service time Ts; in the implementation, instead, we take as input the expected **throughput** because it's easier to reason in term of it and because the service time and the throughput are one the inverse of the other. Also during this report we will talk about throughput instead of service time.

Parallel Architecture Design

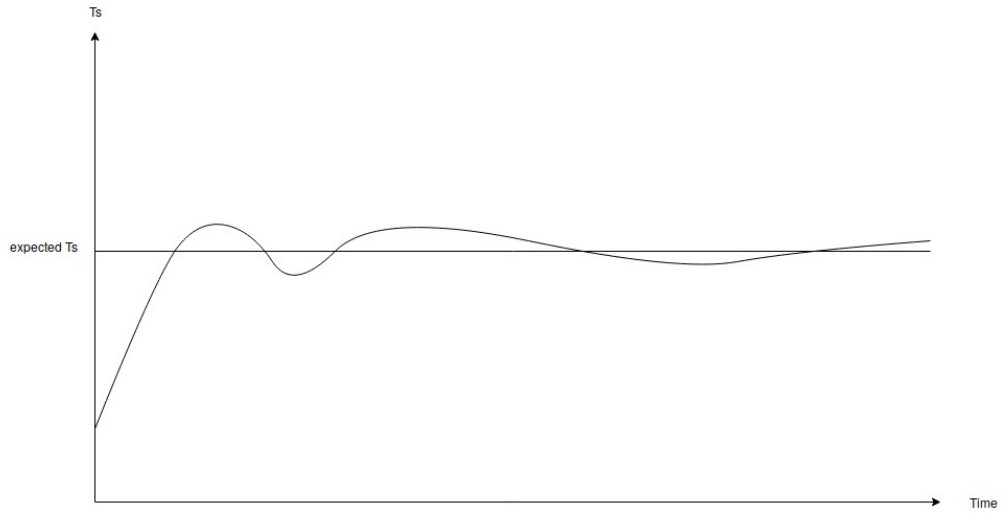


The architecture is a Master-Worker pattern with an additional entity that is the Monitor.
The Master gives the tasks to each worker and, as soon as it collects the result, it will inform the Monitor that may decide to add or remove a Worker.
The Worker will be initialized according to the parallelism degree given by the user and it won't be physically removed: if we do not need a Worker, it will be freezed.
The Monitor gets from the Master the number of task collected so that it can compute the throughput and decide what to do. If it thinks that a Worker should be removed that one will be freezed so that it can be resumed later on if the Monitor decides to add a Worker. This machanism reduces the overhead due to thread initialization and Worker set up.

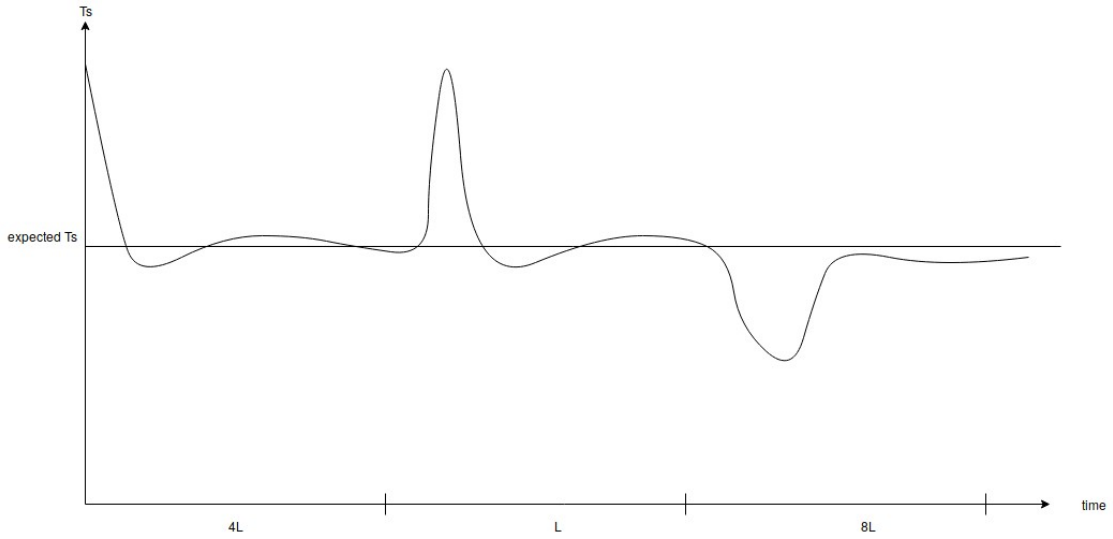
The most relevant implementation details will be explained later in the **Implementation structure and (notable) implementation details** section.

Performace Modelling

The farm will try to maintain a throughput as close as possible to that one taken in input from the user. The performances will depend also on how balanced the workload is: if in input we have a vector with tasks that take more or less the same time to be computed, the farm should stabilize itself around the expected throughput and it won't have many variations.

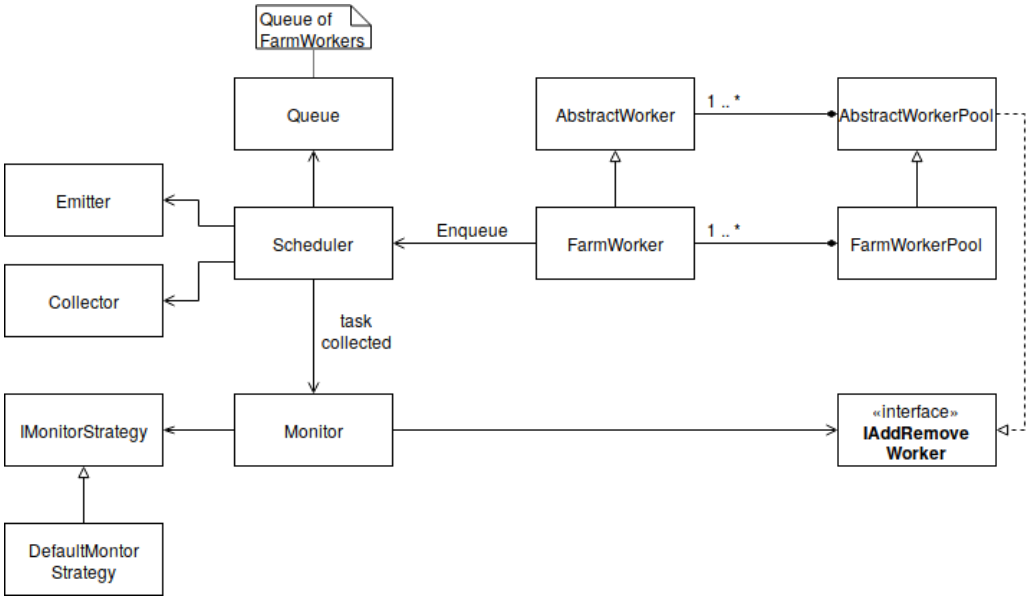


If, instead, the workload is not constant, there will be spikes in the throughput when the unbalanced tasks start to be computed, but after a while the farm will be stabilized again.



In this last figure we can see the expected performances having as input the collection suggestd by the requirements.

Implementation structure and (notable) implementation details



Scheduler and Scheduler Queue

The Scheduler is the core of the architecure. The Queue is used by the FarmWorkers to inform the Scheduler that they are ready to take a new task and to give back the result. The Scheduler pops the Workers from the Queue, gives the result to the Collector and takes the next task from the Emitter to give it to the Worker.
It has been choosen to have just one single Queue to both notify that the worker is ready and to return the results because having one Queue for the result and another to noify the Scheduler would have brought more overhead due to the FarmWorkers syncronization.

The Scheduler runs on the main thread and, after having collected some results, it calls a method of the Monitor (which doesn't have it's own thread, but runs in that one of the Scheduler).

Worker Pool thread

The Worker Pool just manages the set up and the freezing of the Workers. It has been needed to run the WorkerPool on a separate thread because when it receives a request of adding a new worker (different from defrosting an already existing one) it can take care of the overhead of spawning a new thread without blocking the Scheduler. The Scheduler needs to collect the tasks as soon as possible because this can compromise the throughput computation, so it's not good to add to the Scheduler the duty of spawning a new thread.
The WorkerPool won't allow to add more threads than the cores (considered the contexts) to avoid an unbounded increment of the threads to compensate the overhead introduced by the threads theirselves.

FarmWorker Locks

Beside the Queue locks there are a couple more mutexes (implemented in the FarmWorker): one it's used to freeze the worker, the other is used to syncronize it with the Scheduler when

receiving a task (actually there is another lock implemented in the WorkerPool but it's not too relevant). These locks are needed to syncronize the trheads, freeze them, drefrost them etc...
We want to point out that only the Queue lock may represent a relevant overhead because it is shared between all the FarmWorkers, instead the other two locks of the FarmWorker (ralated to the freezing and the task fetching) are just shared between one Worker and the Scheduler or between one Worker and the WorkerPool so that they are contended only between two entities and not between all the Workers.

Default Monitor Strategy: thresholds, window size, trend and average

The MonitorStrategy provided tries to keep some metrics and parameters related to the throughput to take a better decision. When the Monitor receives the ammount of task collected by the scheduler, it computes the throughput and stores it in a vector. The decision is taken only after having collected some "samples" of the throughput. Here it comes the need of a WINDOW_SIZE that allows to keep the recent hystory of the computed throughput. Each time the vector is filled (every WINDOW_SIZE samples) the **trend** and the **average** are computed from the past throughputs. The trend is used to understand if the throughput is increasing or decreasing while the average is used to take a decision based also on the previous measures. When deciding which action to take, also some **threshold** values are considered to have a margin of tollerability to avoid applaying changes every time. Both the WINDOW_SIZE and the threshold values are derived from the imput size and the expected throughput.

The MonitorStrategy may also decide to "refresh" the throughput so that it's computation is not affected too much by the hold computations. By issuing a REFRESH command the monitor will recompute the starting time point used to derive the elapsed time and will consider only the new task collected.

Experimental validation

Inputvectors

Beside the collection suggested by the requirements, several other colllections are provided to test the farm with different input workloads. The function given to the workers is always the same: it actively waits the ammount of millisecond taken as input and returns it.
Some bash scripts are provied to compile and run the experiments with different input values. We will now explain the notation used in the executable to better understand the plots: each main-* has associated a particular kind of vector

main-default	[4L | 1L | 8L] (this is the one suggested in the requirements)
main-constant	[4L]
main-halfdefault	[2L | 1L | 4L]
main-updown	[4L 1L 8L | 4L 1L 8L | 4L 1L 8L]
main-highlow	[8L | 1L]
main-lowhigh	[1L | 8L]

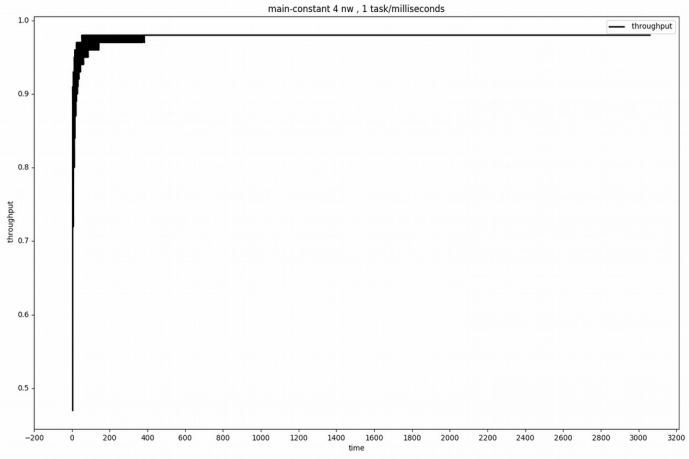
The same notation is used to store the results (in .csv files) and to plot the charts.

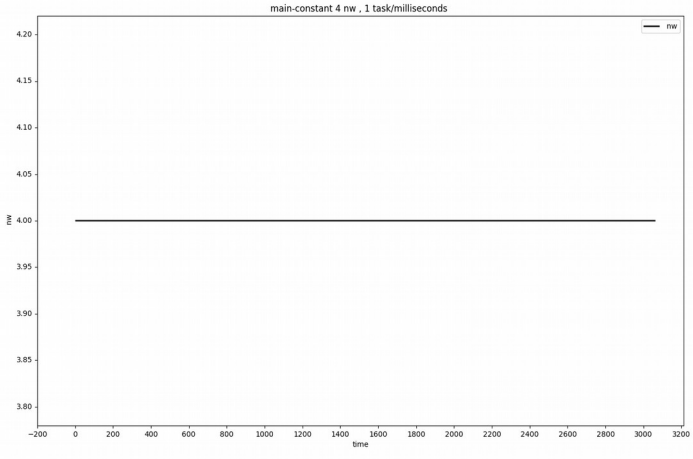
Plots

We will see the obtained results running the experiments on the Xeon Phi KNL. For each experiment we will show two charts: one taking into account the throughput variation and aggiustment, and the other showing the increasing and decreasing of the number of workers. Since the specification requires to test the framework with the "default" collection, more experiments have been performed using this vector in input and changing the parameters.

main-constant

We show first the performances with a constant workload to compare them with the first chart in the **expected performances** section.



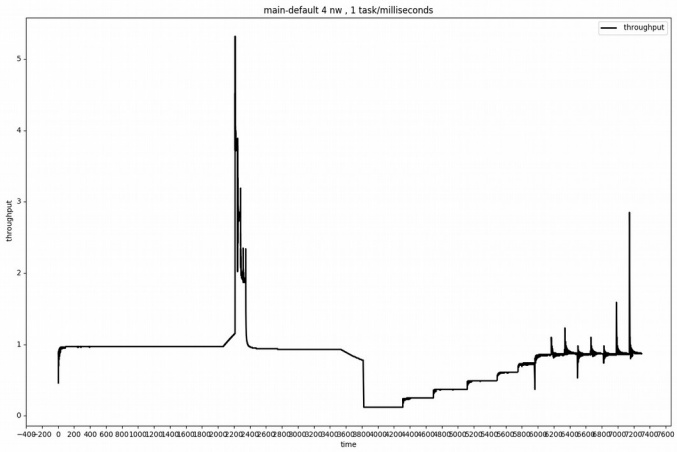


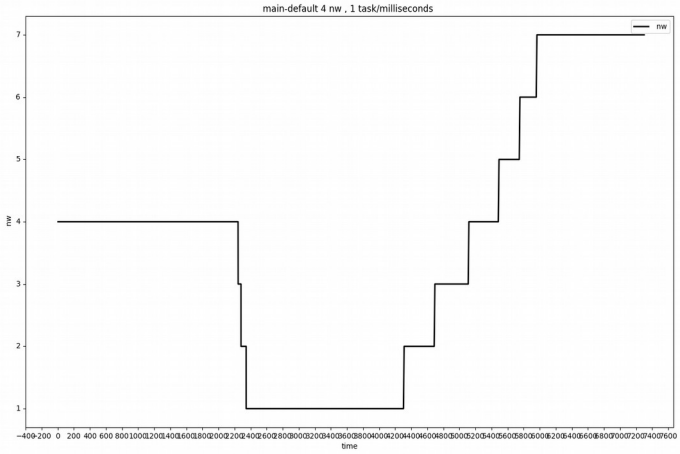
As expected the throughput (left plot) is stable around the given value of 1 task/millisecond and the number of workers (right plot) is constant.

main-default

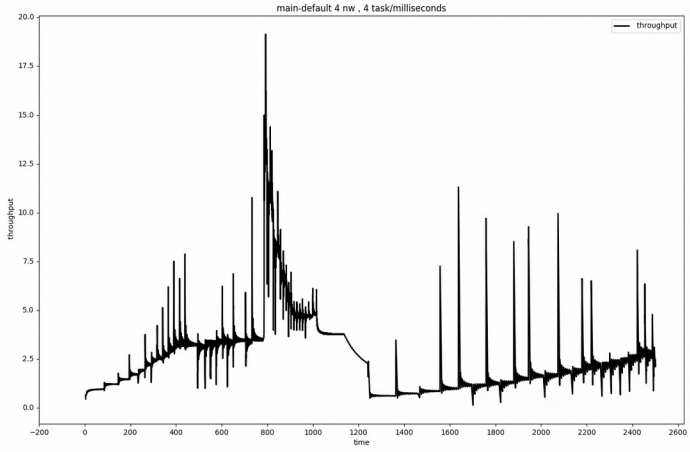
We will see different results obtained by callling the main-default with different parameters.

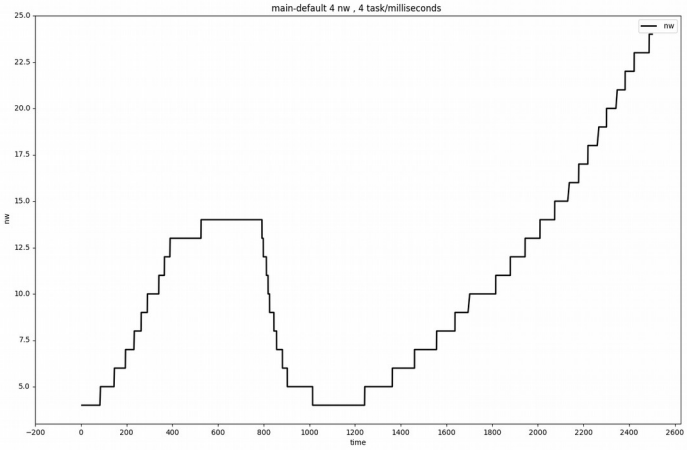
nw = 4, expected throughput = 1 task/millisecond



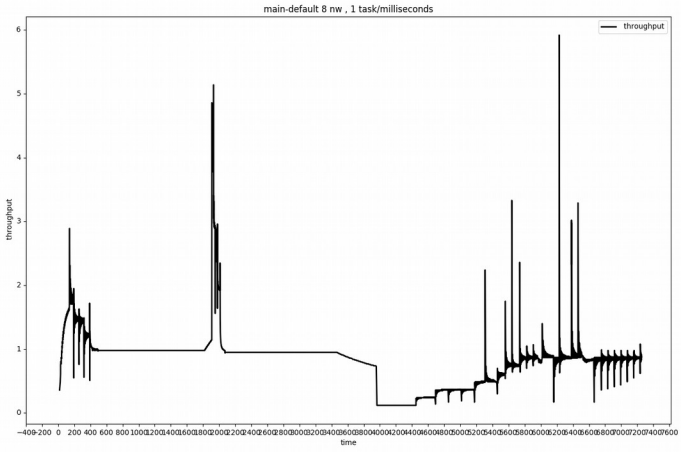


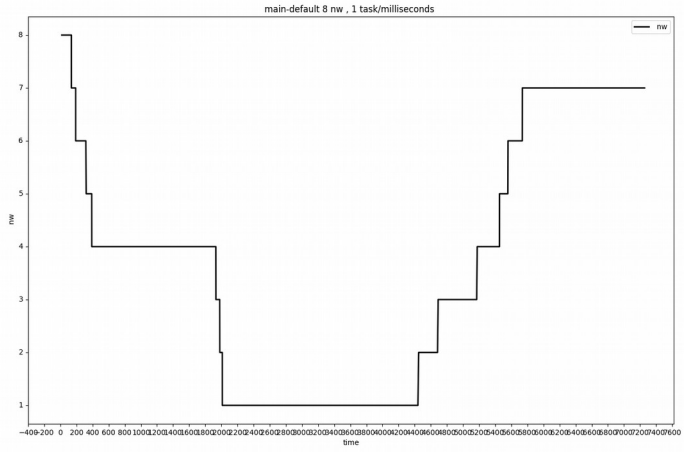
nw = 4, expected throughput = 4 tasks/millisecond





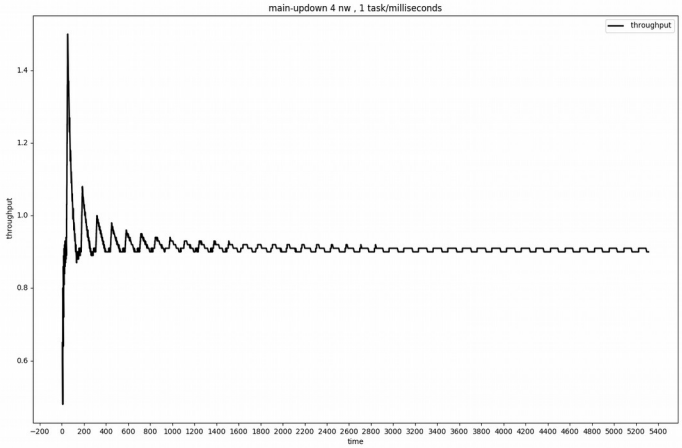
nw = 8, expected throughput = 1 tasks/millisecond

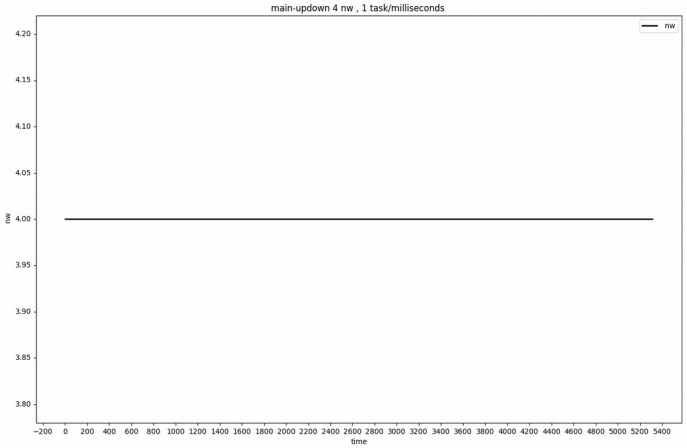




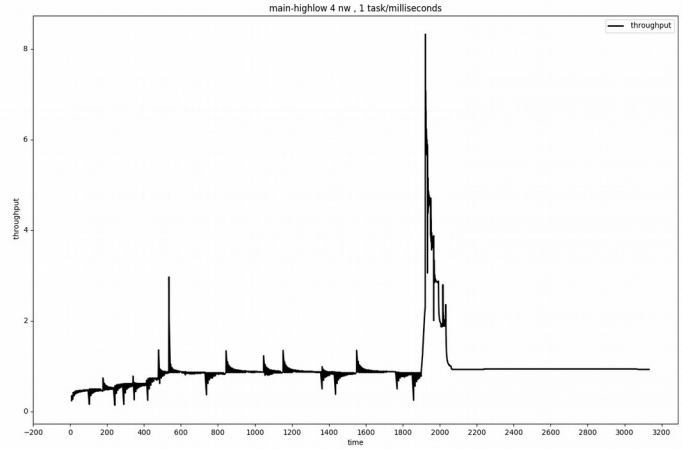
We can say that the trend achieved is the right one: in the above plots it's easy to see that when the throughput is higher than the expected one, the farm reduces the number of workers; when it starts to decrease, the farm increases the number of workers.
We will now show four more experiment results:

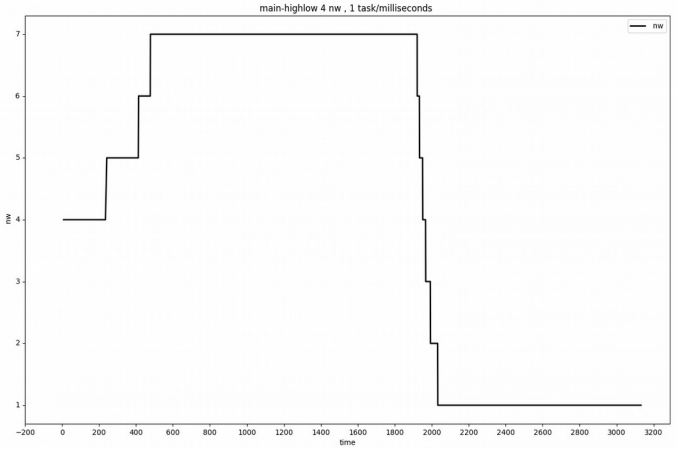
main-updown nw = 4, throughput = 1 task/millisecond



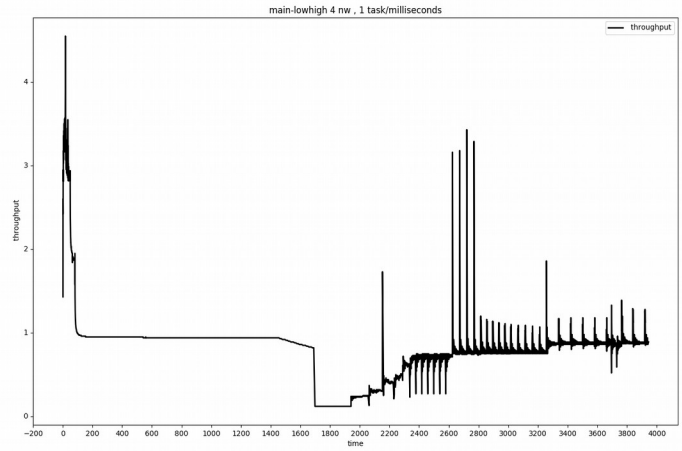


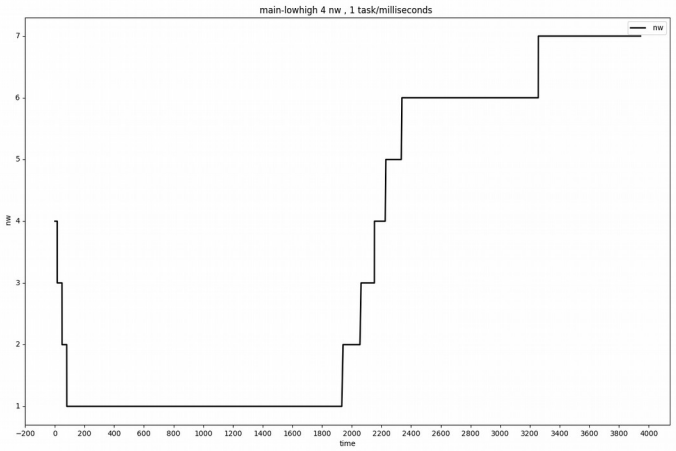
main-highlow nw = 4, throughput = 1 task/millisecond



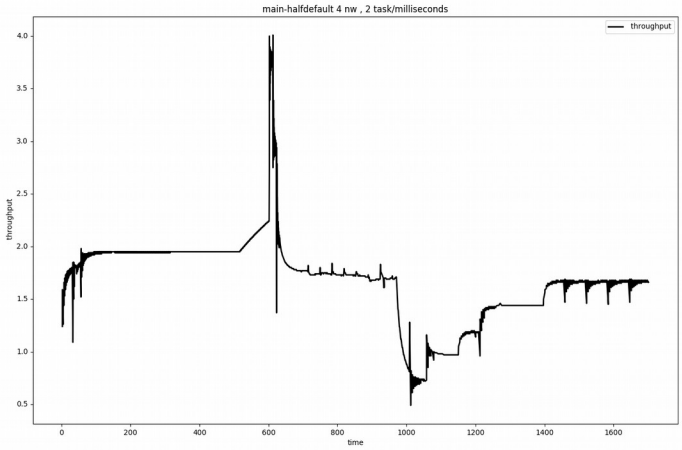


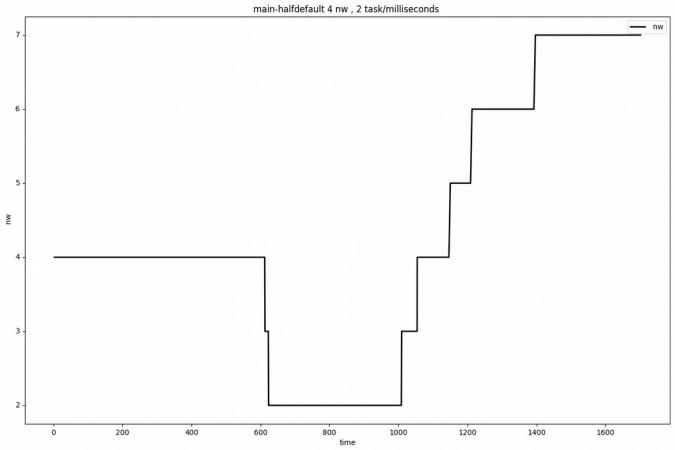
main-lowhigh nw = 4, throughput = 1 task/millisecond





main-halfdefault nw = 4, throughput = 2 task/millisecond





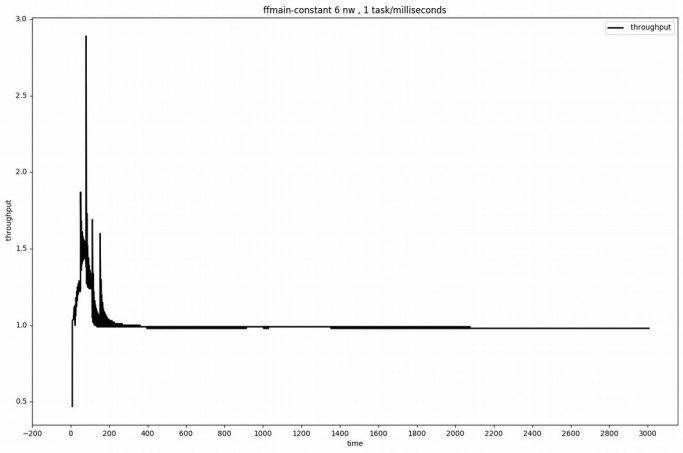
FastFlow implementation

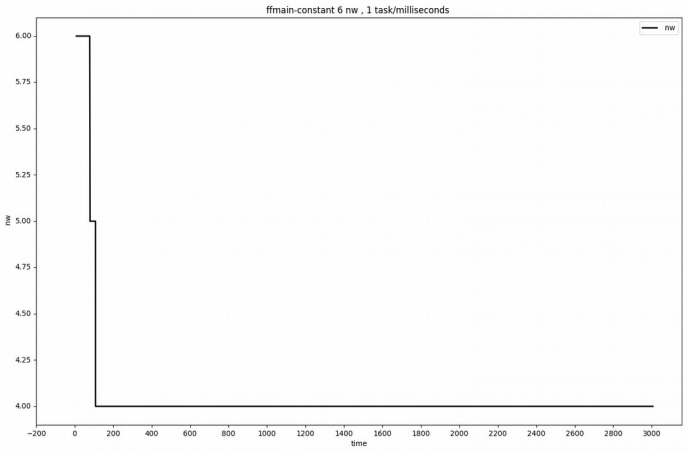
We can now talk about the implementation of the project using the FastFlow low level building blocks.
The parallel architecture is again a Master-Worker and the implementation structure is more or less the same: we have a Scheduler (or Master) implemented as a multi-output node, and some FarmWorker having a feedback channel to the Scheduler.
All the parts concerning the communication and the syncronization are managed by the FastFlow framework so the code is much more lighter than the other using the C++ native threads. We tried also to reuse as much as possible the already implemented classes such as the Emitter, the Collector and , most notably, the Monitor and the MonitorStrategy. This last two classes have been implemented to be highly reusable so that we can have the same Monitor and MonitorStrategy mechanisms in both the implementations. Additionally the FastFlow classes have been integrated in the AutomicFarmBuilder so that it's possible to build an AutonomicFarm using both the implementations.
The most important difference between the two implementation is that we can't properly add new workers (spawning new threads) if we use the FastFlow implementation because the framework allows us only to freeze workers. To run the FastFlow autonomic farm we should provide a higher initial number of worker because during the whole execution the total number of worker will be capped to that value.

Some Plots

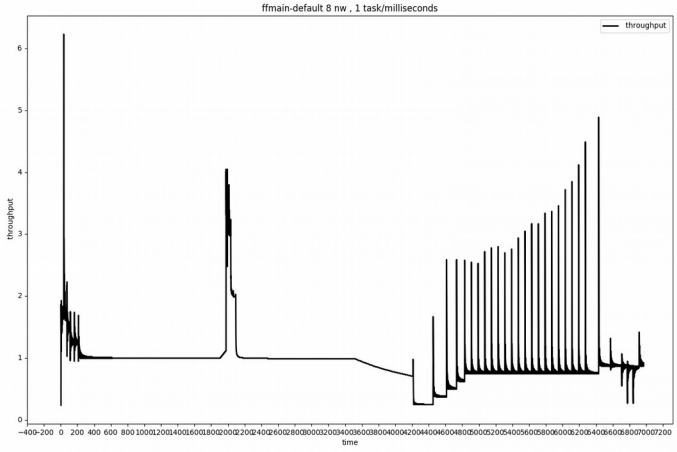
We provide, as before, all the utilities to build, run and plot the farm with different input vectors. The plot that we will show below are just a couple so that can be compared with the chart in the **Performance Modelling** section. It's anyway possible to replicate easily all the experiments done above.

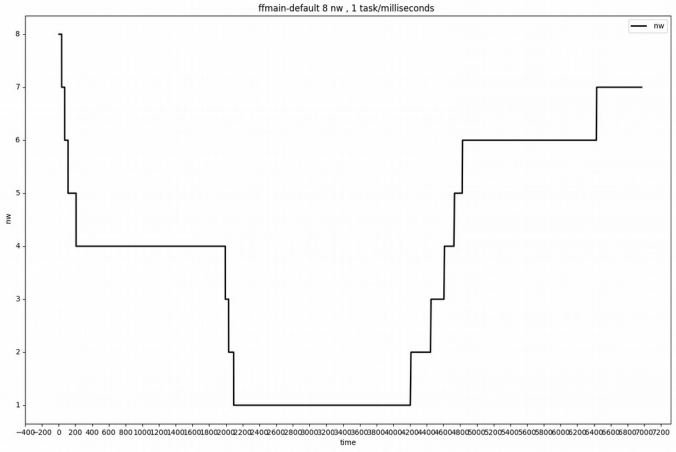
ffmain-constant nw = 6, throughput = 1 task/millisecond





ffmain-default nw = 8, throughput = 1 task/millisecond





ffmain-default nw = 16, throughput = 2 task/millisecond