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# Fixed horizon scheduling as an elementary building block for the fixed horizon with reconfigurations, rolling horizon and real time management production scheduling paradigms

## Abstract

In this paper we present Fixed Horizon Scheduling as an elementary building block for the Fixed Horizon with Reconfiguration, Rolling Horizon and Real Time Management production scheduling paradigms. An outline of the Fixed Horizon Scheduling as an elementary building block is presented. Also, the outline for the algorithms structure for the three scheduling paradigms based on Fixed Horizon as elementary building block are presented.

## Keywords

Fixed Horizon Scheduling, Elementary Building Block, Reconfiguration, Rolling Horizon, Real Time Management Production, Scheduling Paradigms

## 1. Introduction

There are different scheduling paradigms considering production planning and scheduling. One of these scheduling paradigms is the planning and scheduling based on a fixed planning horizon. However due to some errors or deviation on the plan or identification of new market opportunities, some revision on the scheduling plan could be made. This moment of revision could be called as replanning, rescheduling or reconfiguration. Depending of the length of the planning horizon and the reconfiguration period it could be considered another different scheduling paradigms such as the fixed horizon with reconfigurations, rolling horizon and real time management.

The algorithms development for all of these three (if the fixed horizon with reconfigurations is considered as a variant of the fixed horizon) scheduling paradigms could be based on an elementary building block.

This paper presents the fixed horizon scheduling paradigm as an elementary building block for constructing the Fixed Horizon with Reconfiguration, Rolling Horizon and Real Time Management production scheduling paradigms, and presents the outline for all scheduling paradigms considered.

## 2. Three Production Scheduling Paradigms

The production scheduling paradigms considered in this paper are: (1) Fixed Horizon (FH) and its variant Fixed Horizons with Reconfigurations (FHR), (2) Rolling Horizon and (3) Real Time Management. The FH and RH paradigms are not new as they has been discussed since the 70's. In fact,

the concept of RH in planning is a concept that overlap the FH (Tendulkar, 1977).

These scheduling paradigms were presented in Putnik et al. (2015). FH considers the scheduling plan till the completion time or “Time-To-Market” (TTM) of all jobs (Figure 1). If reconfigurations are considered, FHR considers in each reconfiguration the scheduling plan till the completion time or TTM of all jobs (Figure 2). RH defines a rolling period on which the scheduling plan is made, and at each reconfiguration a new scheduling plan for the next rolling period (Figure 3). RTM in its abstract focuses on the scheduling plan between reconfigurations (Figure 4). The true RTM considers the scheduling plan at each moment of time (Figure 5).

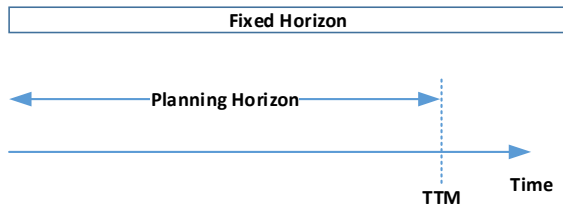


Figure 1. FH production scheduling paradigm

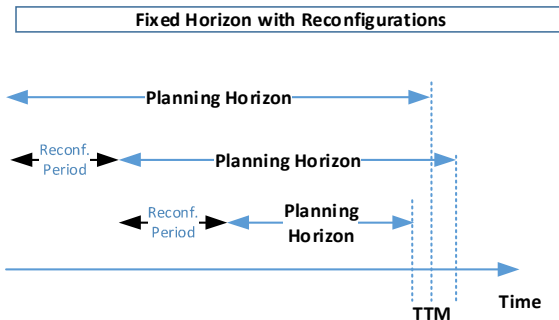


Figure 2. FHR production scheduling paradigm

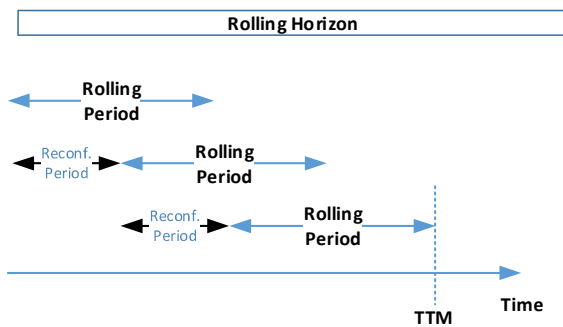


Figure 3. RH production scheduling paradigm

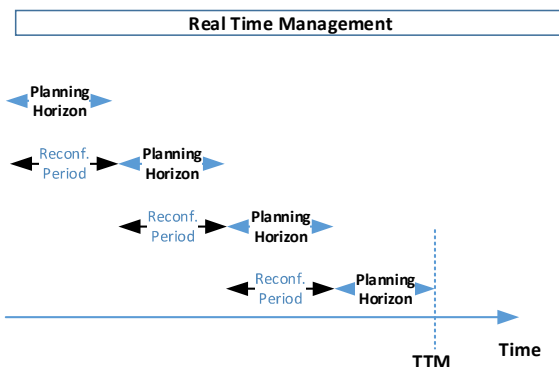


Figure 4. RTM production scheduling paradigm

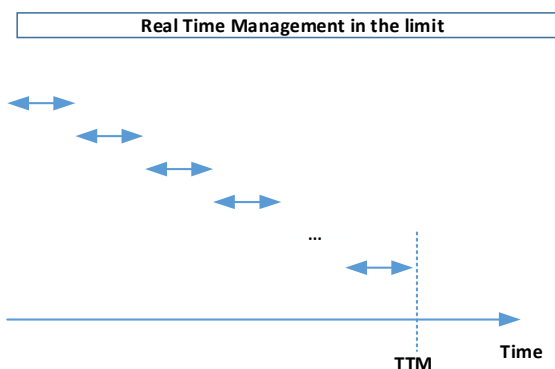


Figure 5. RTM in the limit

### 3. Fixed Horizon Scheduling as an Elementary Building Block

Fixed horizon scheduling could be interpreted as the scheduling for a specific interval which is delimited by the allocation of all operation of jobs, at the input, to machines/resources. This allocation determines the interval of time for processing, that is the completion time of the given set of jobs (in some other contexts could be called Time-to-Market (TTM)) (Figure 6). So, it could be said that the schedule is made from an initial point in time till the completion value.

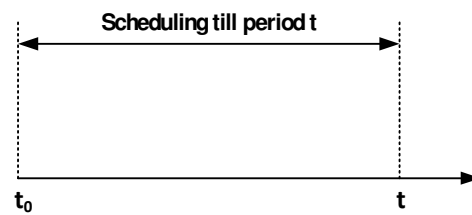


Figure 6. Fixed horizon scheduling as the elementary building block

If a reconfiguration occurs, it is necessary to reschedule again from the point of reconfiguration till the completion time value. This implies the adoption of the “Fixed Horizon with Reconfiguration” scheduling paradigm. In this case the state of the schedule at the moment of the reconfiguration is considered as the initial state on the replanning till the completion time value. This process is repeated as many times as needed.

Each rescheduling, or reconfiguration, when abstracting previous and subsequent schedulings, could be considered as the fixed horizon scheduling, which initial state is equal to the state of previous schedule at the moment of starting the rescheduling, or reconfiguration, in case. This consideration is applied for any rescheduling, or reconfiguration, and therefore the fixed horizon scheduling could be considered as the “elementary building block” for constructing the fixed horizon scheduling with reconfigurations (Figure 7).

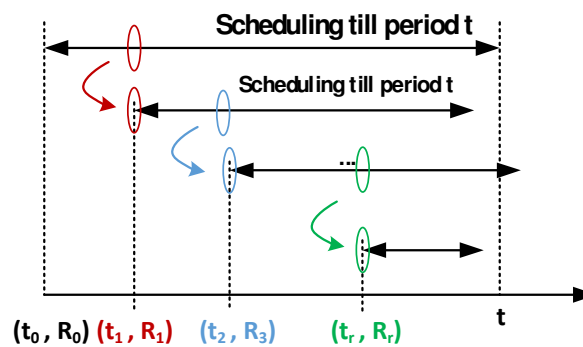


Figure 7. Fixed horizon scheduling as the elementary building block for fixed horizon scheduling with reconfiguration

In the Rolling Horizon scheduling paradigm the specific interval for scheduling is considered as a “rolling period”, which is shorter than the interval for the previous paradigm<sup>1</sup>. However, there is still a “planning horizon” for each rolling period. In this case, if a reconfiguration occurs, it is necessary to reschedule again from the point of reconfiguration till the “rolling period”, and the state of the schedule at the moment of the reconfiguration is considered as the initial state on the rescheduling till the “rolling period”. This process is repeated as many times as needed.

Each rescheduling, or reconfiguration, when abstracting previous and subsequent schedulings for each rolling period, could be considered as the fixed horizon scheduling, which initial state is equal to the state of previous schedule at the moment of starting the rescheduling, or reconfiguration, in case. This consideration is applied for any rescheduling, or reconfiguration, and therefore the fixed horizon scheduling could be considered as the “elementary building block” for constructing the rolling horizon scheduling (Figure 8).

<sup>1</sup> Or previous two paradigms if Fixed Horizon scheduling and Fixed Horizon scheduling with reconfigurations are considered as two paradigms.

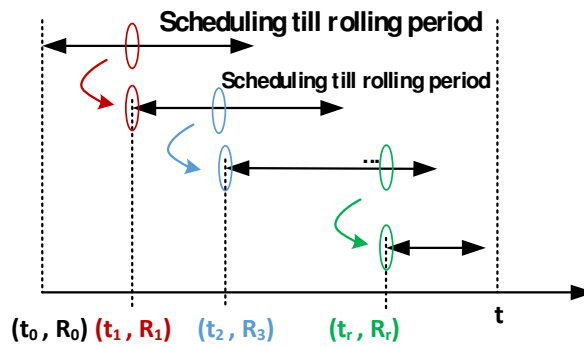


Figure 8. Fixed horizon scheduling as the elementary building block for rolling horizon scheduling

In the case of “Real Time Management” scheduling paradigm it is considered only the scheduling between two times of reconfigurations. In this case, the moment of reconfiguration is at the end of the previous scheduling horizon. In this sense, the real time management scheduling could be considered as a sequence of fixed horizon schedules. However, there is no reason to have the real time management scheduling horizon be longer than scheduling horizons in previous paradigms. Actually, in accordance with the concept of “real time”, a real time management scheduling implies the capacity for making schedule at each instant of time. Consequently, it implies that the planning horizon is, in the limit, equal to one time unit.

This process is repeated, in the limit, each one time unit in sequence as shown in Figure 9.

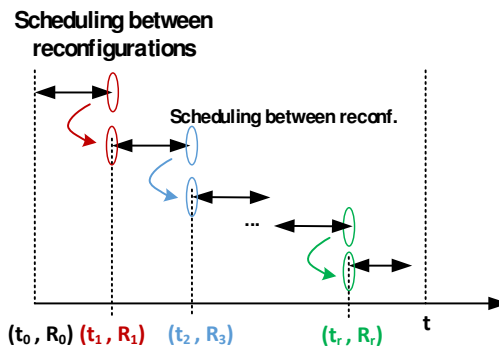


Figure 9. Fixed horizon scheduling as the elementary building block for real time management scheduling

It is necessary to note that the planning horizon, in the limit, is equal to one, and fixed horizon scheduling has to be applied repeatedly for each time unit. In this sense, the fixed horizon scheduling could be considered also as the “elementary building block” for constructing the real time management scheduling.

#### 4. Outline of the Fixed Horizon as elementary building block routine (algorithm)

As described in the previous chapter, the fixed horizon scheduling is considered as the “elementary building block” for constructing all the scheduling paradigms presented.

##### 4.1 Terms index for the Fixed Horizon as elementary building block outline presentation

The terms index for the fixed horizon scheduling as elementary building block will be presented. The following lists, variables, indexes and tables were considered.

- **Lists**
  - `operation_schedule_list`: ordered list that contains all the operations to be scheduled
  - `executable_operation_schedule_list`: list of the operations that can be scheduled for the respective time  $t$
  - `processing_operation_schedule_list`: list of processing operations

- **Variables**
  - T: time unit(s) defined to be large enough to execute all operators
  - : absolute time unit
  - nss: new start state of the system description for state  $\tau$
  - t: relative time unit
  - operation\_schedule: Processing (allocation) of operation j of job i on a machine k for d time units
  - d: time units attributed to finish the operation
- **Indexes**
  - i: index for the job
  - j: index for the operation
  - k: index for the machine
- **Tables**
  - system\_state\_description: triangular inferior matrix for time unit(s)
- **Other**
  - FHEB: algorithm for fixed horizon scheduling as elementary building block

#### 4.2 Outline of the Fixed Horizon as elementary building block

The outline of the FHEB routine or algorithm is described below:

```

FHEB(T, •, nss)
For t:=1 to T
  •:= t-1
  ForAll operation_schedule in operation_schedule_list:
    If (previous_operation_id(operation_schedule)  $\in$ 
      concluded_operation_schedule_list  $\vee$  operation_id(operation_schedule)==1 )
      then
        Select machine k by a resource selection criteria for operation_schedule
        Append operation_schedule to executable_operation_schedule_list
      End If
    End For
  ForAll executable_operation_schedule in executable_operation_schedule_list:
    Remove executable_operation_schedule from operation_schedule_list
    Append executable_operation_schedule to processing_operation_schedule_list
    Set (Occupied Mk Ji OPj (d)) in system_state_description
  End For
  ForAll processing_operation_schedule in processing_operation_schedule_list:
    If processing_operation_schedule  $\notin$  executable_operation_schedule_list then
      If length(processing_operation_schedule) > 1 then
        Update (Occupied Mk Ji OPj (d-1)) in system_state_description
      Else
        Update (Available Mk) in system_state_description
      End If
    End If
  End For
  Empty the executable_operators_list
End For
Return •+1

```

## 5. Outline of the algorithms structure for the scheduling paradigms based on Fixed Horizon as elementary building block

The outline of the algorithms for FH, FHR, RH and RTM based on FH as elementary building block are described in this chapter.

### 5.1 Terms index for the algorithms' presentation

The terms index used by the algorithms are described as follows:

- **Variables**
  - T: time unit(s) defined to be large enough to execute all operators
  - : absolute time unit
  - rp: Reconfiguration period
  - rt: Reconfiguration time
  - rh: Rolling Horizon
  - time: Completion time
- **Other**
  - FH: algorithm for fixed horizon scheduling
  - FHR: algorithm for fixed horizon with reconfigurations scheduling
  - RH: algorithm for rolling horizon scheduling
  - RTM: algorithm for real time management scheduling

### 5.2 Algorithm outline for the Fixed Horizon production scheduling

The algorithm for the fixed horizon scheduling is given below:

```
FH (T, •)
Execute FHEB (T, •, nss)
Return •
```

### 5.3 Algorithm outline for the Fixed Horizon production scheduling with reconfigurations

The algorithm for the fixed horizon scheduling with reconfigurations is given below:

```
FHR (T, •, rp, rt)
Execute FHEB (T, •, nss)
nr:=•/rp
nra:=roundup_integer(nr)
For r:=1 to nra
    •:=r*(rp+rt)
    Execute FHEB (T, •, nss)
    time:=•+ r*(rp+rt)
End For
Return time
```

### 5.4 Algorithm outline for the Rolling Horizon production scheduling

The algorithm for the rolling horizon production scheduling is given below:

```
RH (T, •, rp, rt, rh)
Execute FHEB (T, •)
nr:=•/rp
nra:=roundup_integer(nr)
T:=rh
For r:=1 to nra
    •:=r*(rp+rt)
    Execute FHEB (T, •, nss)
    time:=•+ r*(rp+rt)
End For
Return time
```

## 5.5 Algorithm outline for the Real Time Management production scheduling

The algorithm for the real time management production scheduling is given below:

```

RTM(T, •, rp, rt)
Execute FHEB(T, •)
nr:=•/rp
nra:=roundup_integer(nr)
T:=rp
For r:=1 to nra
    •:=r*(rp+rt)
    Execute FHEB(T, •, nss)
    time:=•+ r*(rp+rt)
End For
Return time

```

## 6. Conclusions

Production scheduling paradigms such as Fixed Horizon with reconfigurations, Rolling Horizon and Real Time Management can be represented in higher level algorithms which use fixed horizon paradigm algorithm as an elementary building block.

Using Fixed Horizon as elementary building block contributes to the following:

- Facilitates implementation of other paradigms, as shown in Chapter 5;
- Represents a theoretical contribution to specification of other more complex scheduling paradigms;
- Facilitates training and learning of scheduling function in production systems.

Future work could include investigation of relationship among the three scheduling paradigms and for validation of each one in comparison with others. In other words, the following hypotheses could be investigated:

- 1) RTM paradigm is more suitable for production scheduling in a factory workshop under conditions of dynamic environments than the "Fixed Horizon" and "Rolling Horizon" paradigm;
- 2) RTM paradigm is more suitable for production scheduling in ubiquitous production networks under conditions of dynamic environments than the "Fixed Horizon" and "Rolling Horizon" paradigm;
- 3) RTM paradigm contributes to economic and environmental sustainability.

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